Physics at LHC 2012

4-9 June 2012, Vancouver, BC

PARTICLE IDENTIFICATION WITH THE ALICE DETECTOR AT THE LHC

C. Zampolli – INFN Bologna
On behalf of the ALICE Collaboration

Outline

- The ALICE detector
- Particle Identification in ALICE
  - Barrel detectors
  - Single-arm detectors
  - Topological PID
- ALICE Particle Identification results
- Conclusions

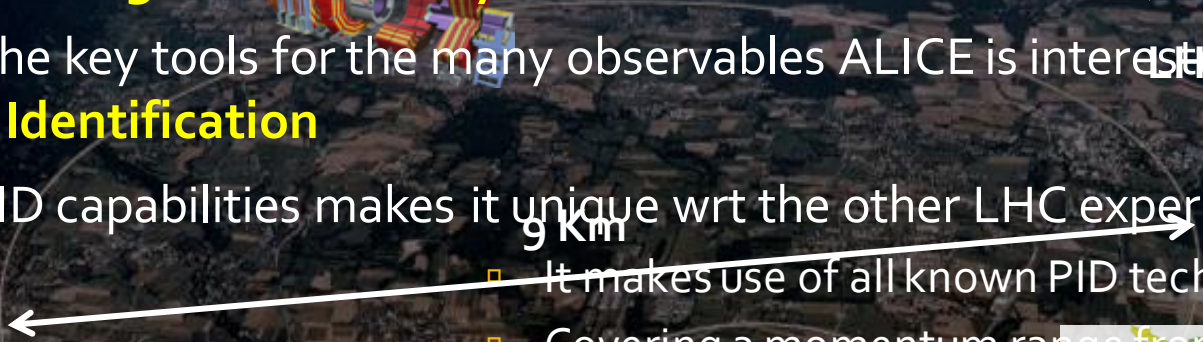
See also:

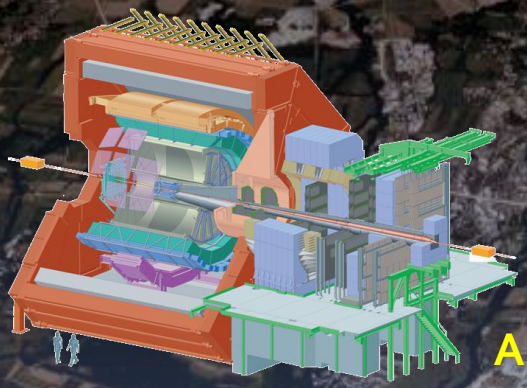
- Recent results, P. Kuijer (4/6)
- HI at LHC, C. Loizides (5/6)
- PID in pp, A. Ortiz Velasquez (5/6)
- Correlations, D.J. Kim (5/6)
- Strangeness, B. Abelev (5/6)
- Soft QCD and Diffractive at LHC, E. Scapparone (5/6)
- HF in PbPb, Y. Pachmayer (5/6)
- HF in pp, P. Antonioli (7/6)
- Quarkonia in pp, L. Bianchi (5/6)
- Quarkonia in PbPb, H.D.A. Pereira Da Costa (5/6)

The ALICE Detector

The ALICE Experiment at LHC

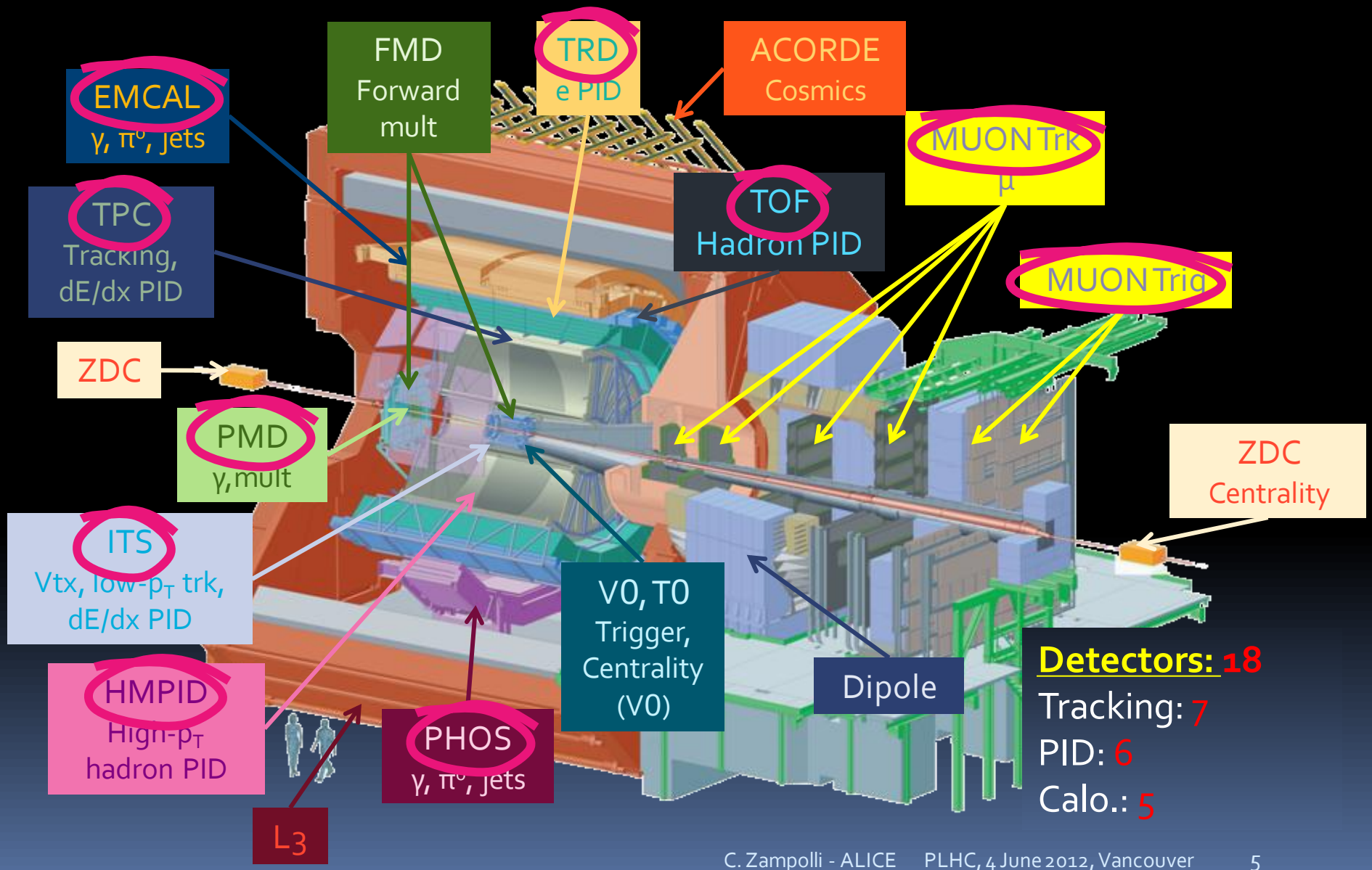
- A Large Ion Collider Experiment is the experiment at the CERN Large Hadron Collider (LHC) dedicated for heavy-ion physics
  - Genuine interest also in pp and pA
- **The ultimate goal is the study of the Quark Gluon Plasma (QGP)**
- One of the key tools for the many observables ALICE is interested in is **Particle Identification**
- ALICE PID capabilities makes it unique wrt the other LHC experiments
  - It makes use of all known PID techniques
  - Covering a momentum range from 0.1 to ~100 GeV/c





A Large Ion Collider Experiment

ALICE Detectors - Setup



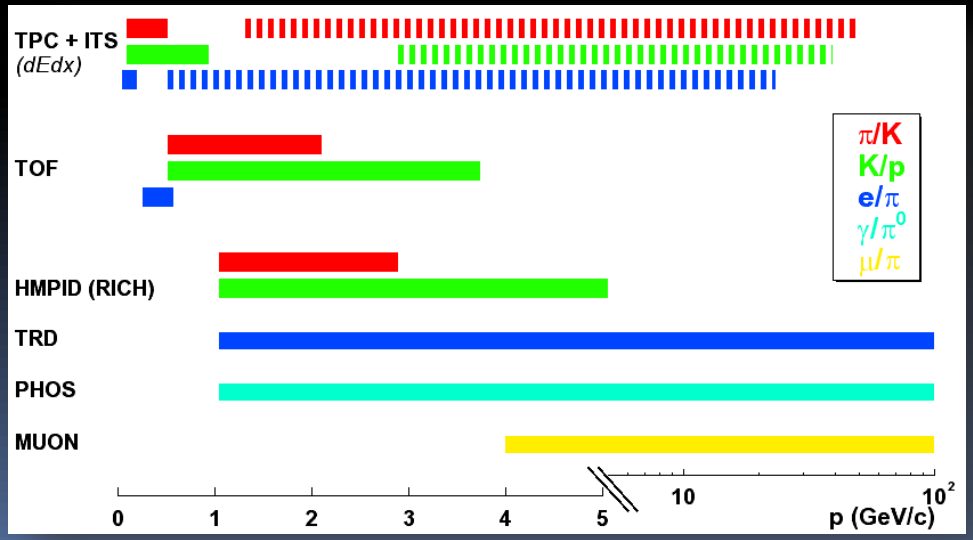
The ALICE PID techniques

Barrel Detectors

- Energy loss
  - ITS
  - TPC
- Transition radiation
  - TRD
- Time of Flight
  - TOF

Single-arm Detectors

- Calorimetry
  - PHOS
  - EMCAL
- Muon Spectrometry
  - MUON
- Cherenkov Radiation
  - HMPID
- Preshower
  - PMD



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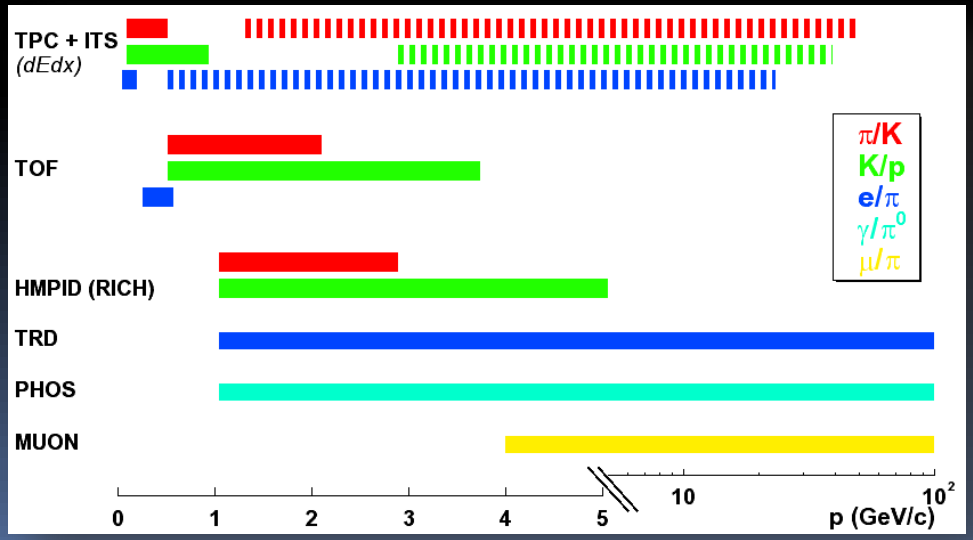
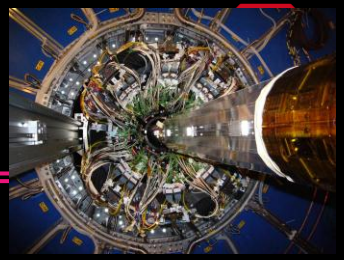


Decay Topology

- Topological PID
  - ITS

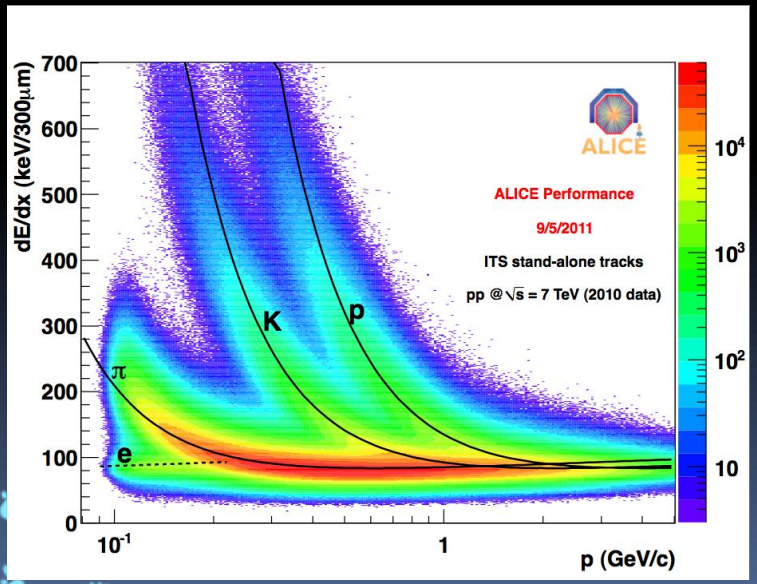
PID in the barrel

PID with the ALICE ITS

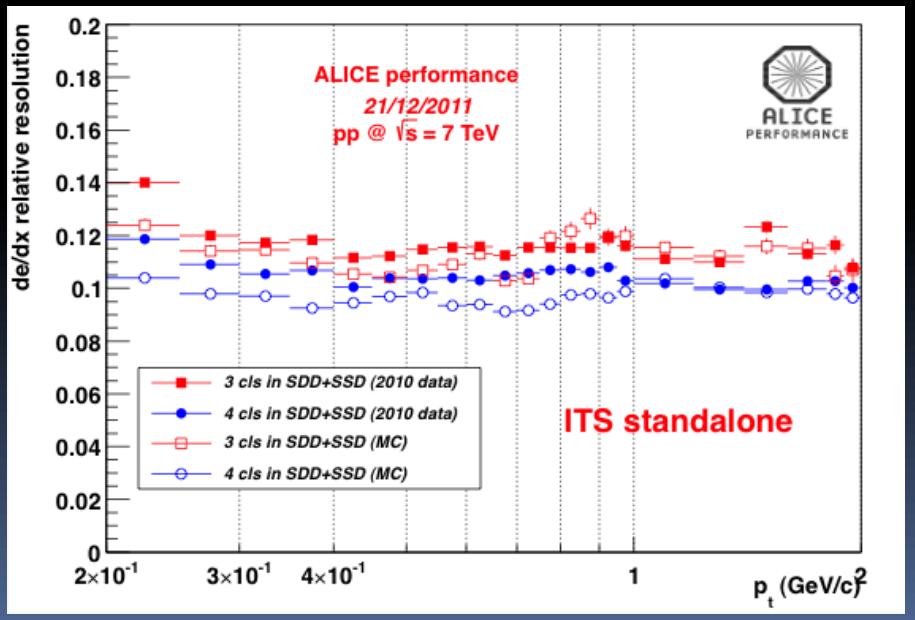


- The Inner Tracking System ($|\eta| < 0.9$)
  - Six layers, three technologies: SPD, SDD, SSD
  - Primary and secondary vertex reconstruction
  - Tracking + standalone reconstruction
  - PID via dE/dx from SDD and SSD analog read-out
    - In the low p_T region, down to 100 MeV for π standalone tracking

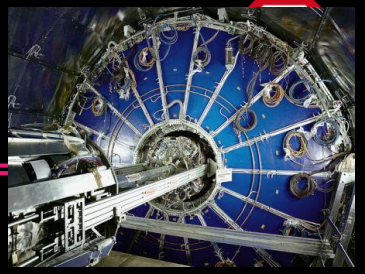
- Truncated mean - (weighted) average – out of 3 or 4 layers



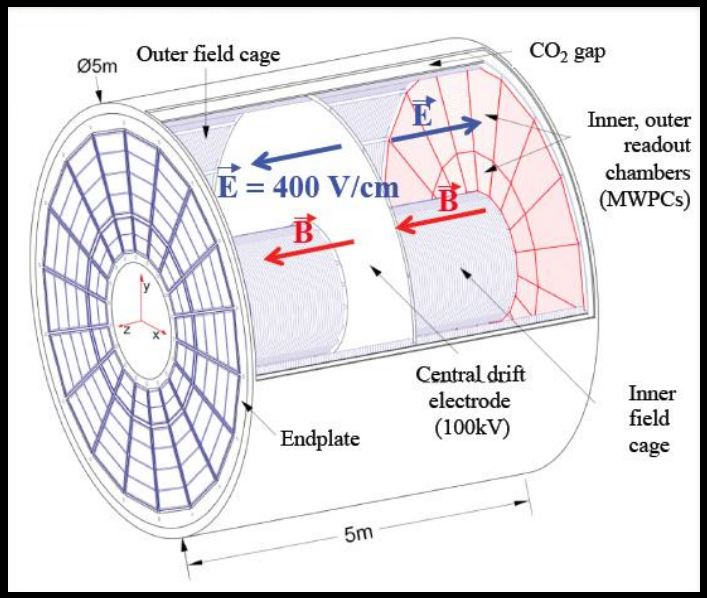
- Resolution $\sigma_{dE/dx}$ ~ 10-15%



The ALICE TPC



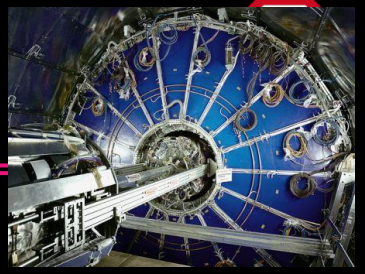
- Large TPC optimized for high-multiplicity environment



- L=5 m, Ø = 5 m, 92 m^3 (inner radius ~80 cm)
- Material (η=0): 3% X_0
- Drift gas: $Ne/CO_2/N_2$ (86/9.5/4.5%)
- Drift time: 92 μs
- ~ 560000 pads
- Calibration with laser, krypton, cosmics, w/ and w/o B field

- Efficient tracking (~80%) in $|\eta| < 0.8$, $\sigma(p_t)/p_t \sim 5\%$ (simulation, current performance within expectations)
- Momentum resolution (TPC+ITS) $\sigma(p_t)/p_t < 2.5\%$ up to 10 GeV/c
- Two-track resolution < 10 MeV
- PID (truncated mean over a max of 159 signals) with $\sigma_{dE/dx}$ ~5% (isolated tracks, max number of clusters)
- Space-point resolution 0.8 (1.2) mm in xy (z)

The ALICE TPC



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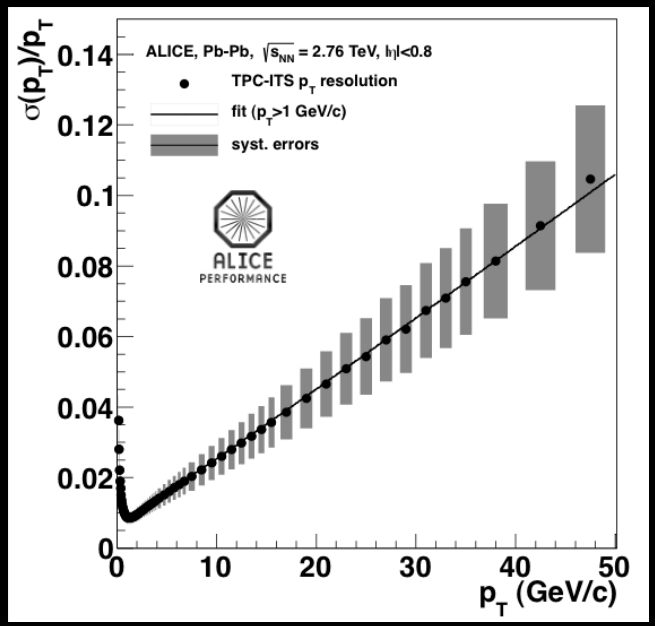

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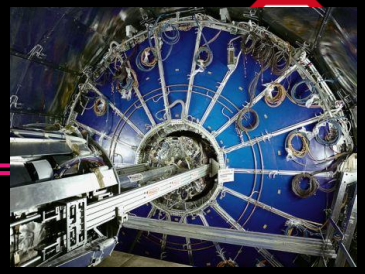
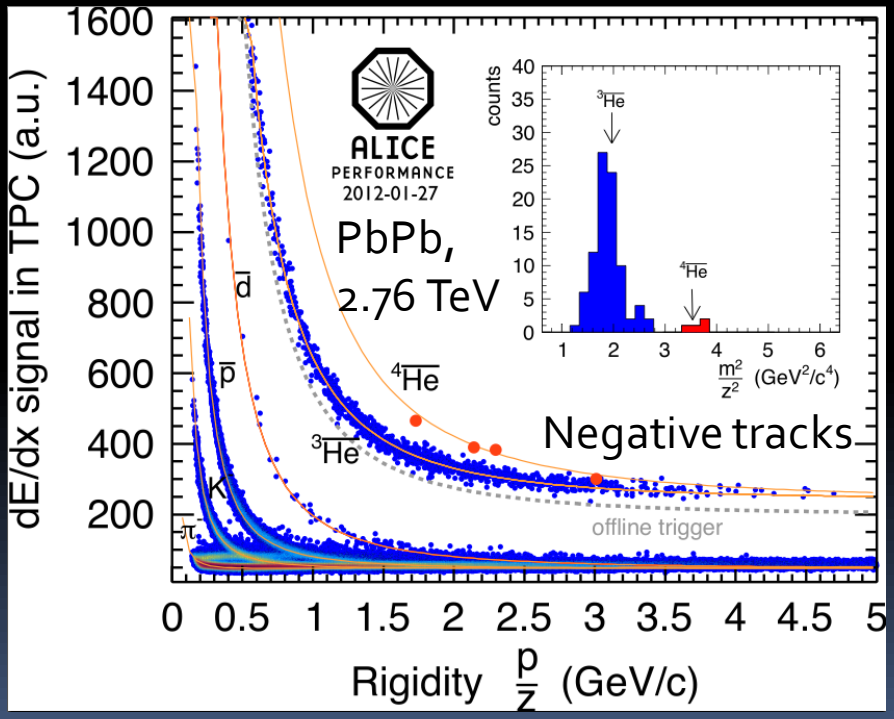
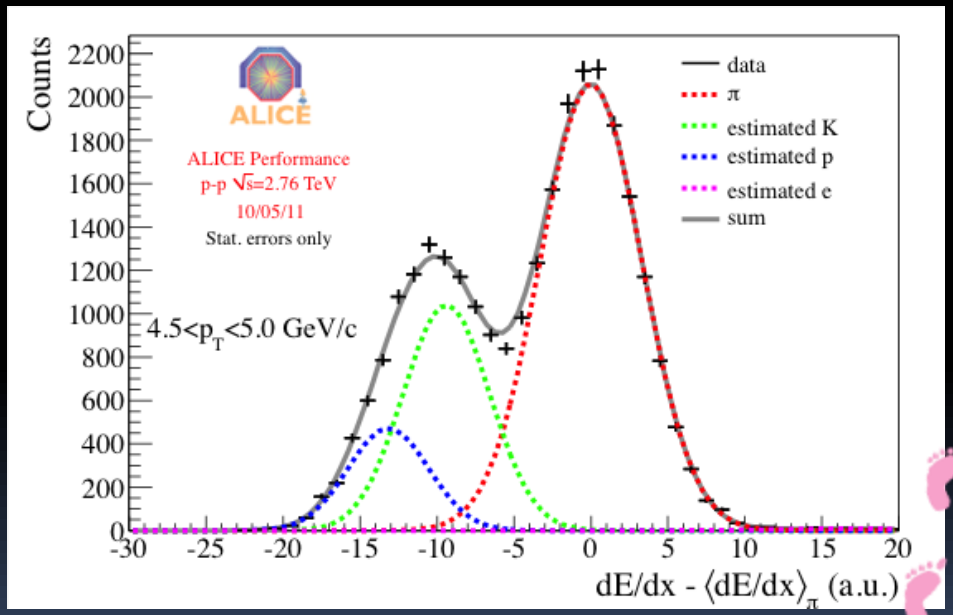
PID with the ALICE TPC



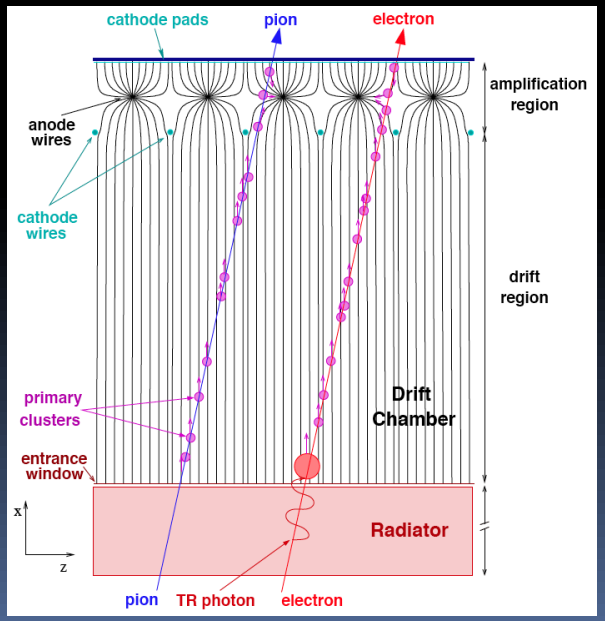
- Wide dynamic range, up to ~26 MIP
  → light nuclei
- Track-to-Track ID (n-σ cut) in the $1/\beta^2$ region
- PID in the relativistic rise using statistical approaches

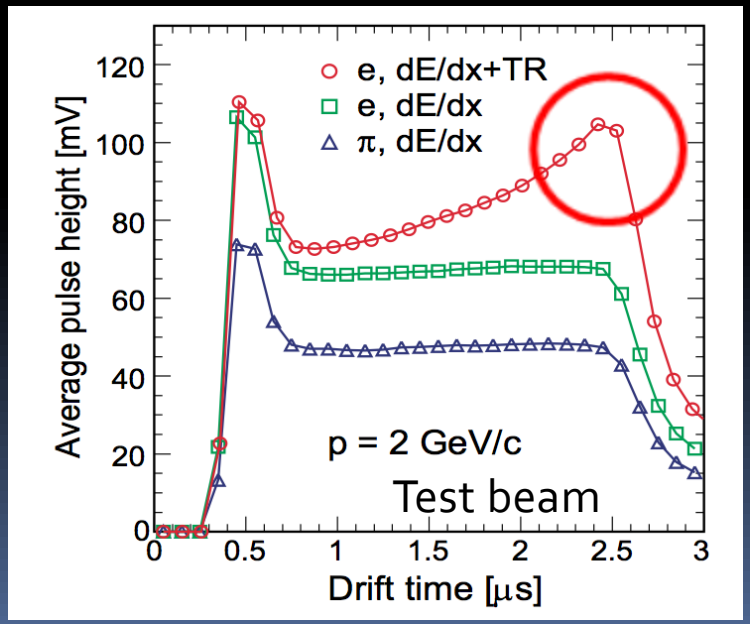




The ALICE TRD

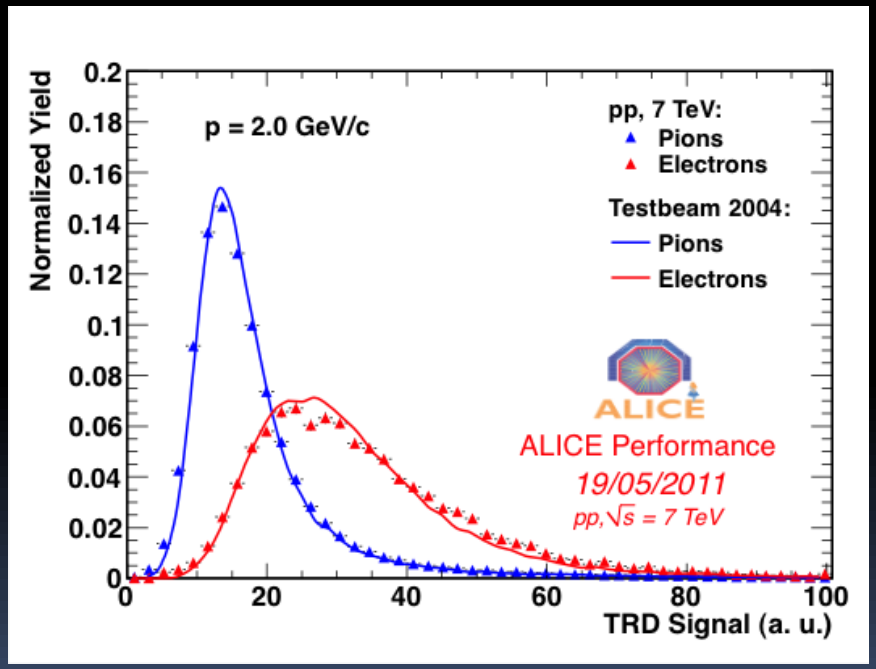
- 6 layer Transition Radiation Detector, with 5 longitudinal stacks ($|\eta| < 0.9$ and full ϕ)
- At the LHC energies, only electrons can emit TR (γ>1000 needed)
  - Electron ID in the momentum range p > 1 GeV/c, with pion rejection factor ~100
- Signal shows:
  - Peak at early times → amplification region
  - Peak at late times (for electrons!) → Transition Radiation

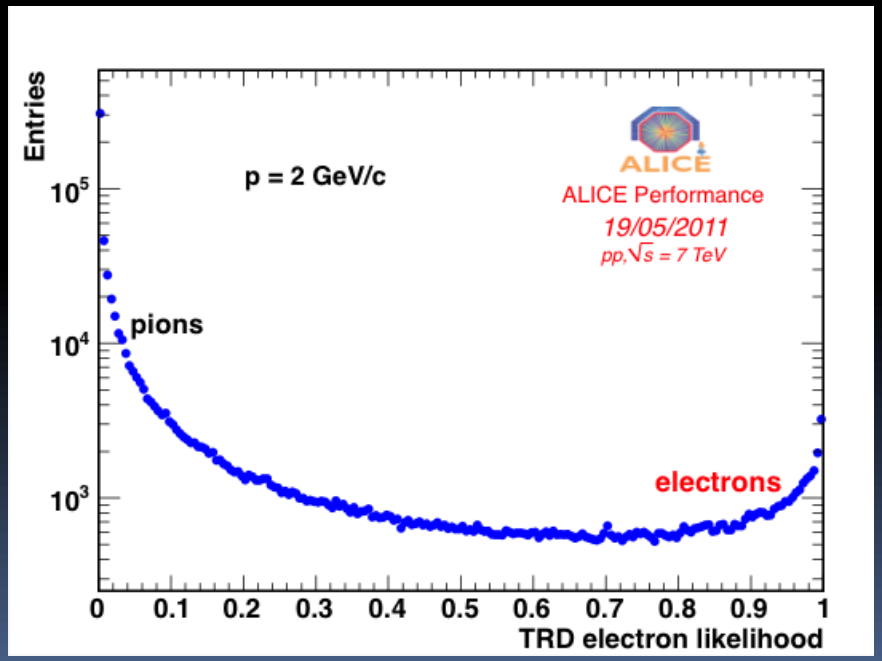




PID with the ALICE TRD

- 1d likelihood method used at present, using the different signal distributions for pions and electrons
  - 2d likelihood + neural networks under study





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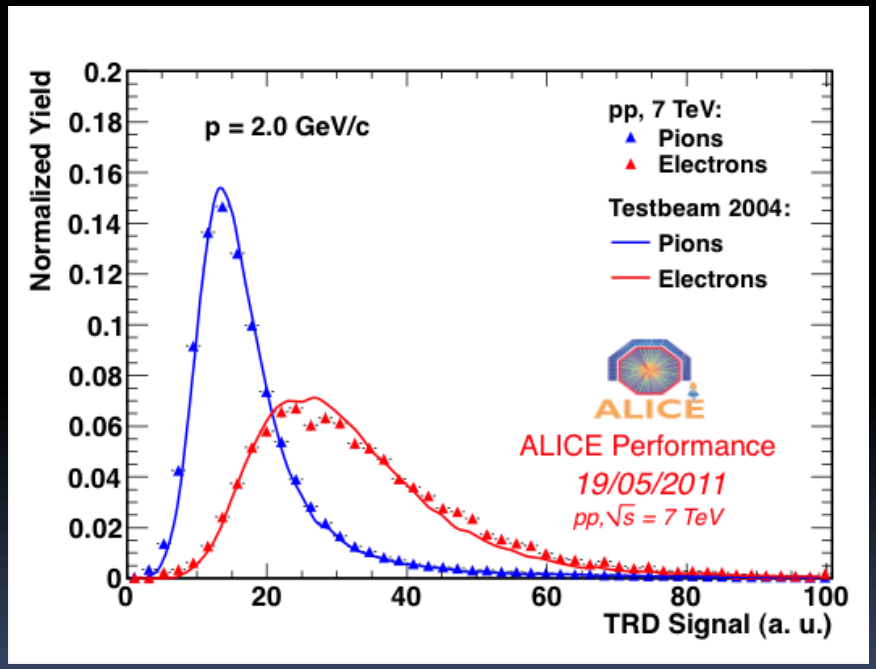
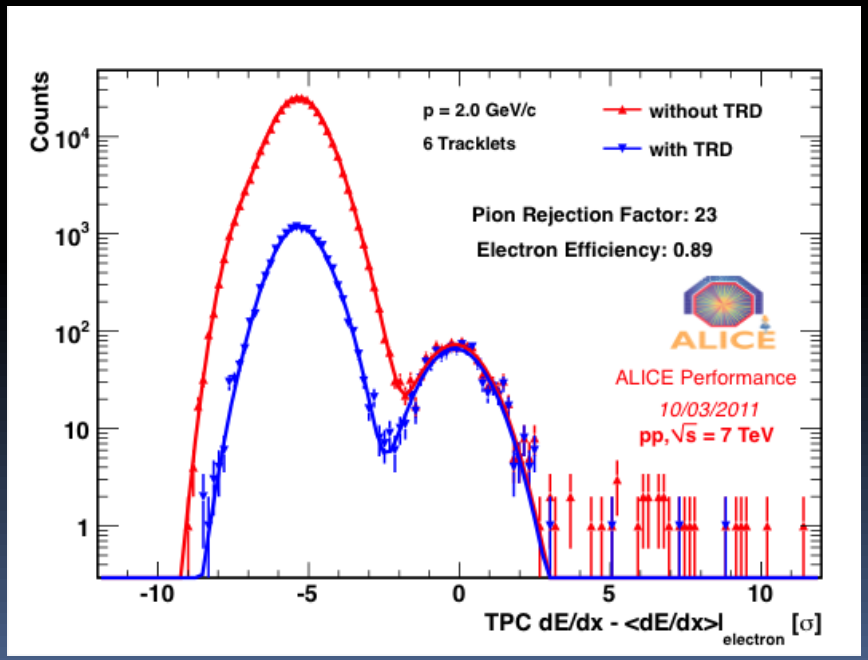
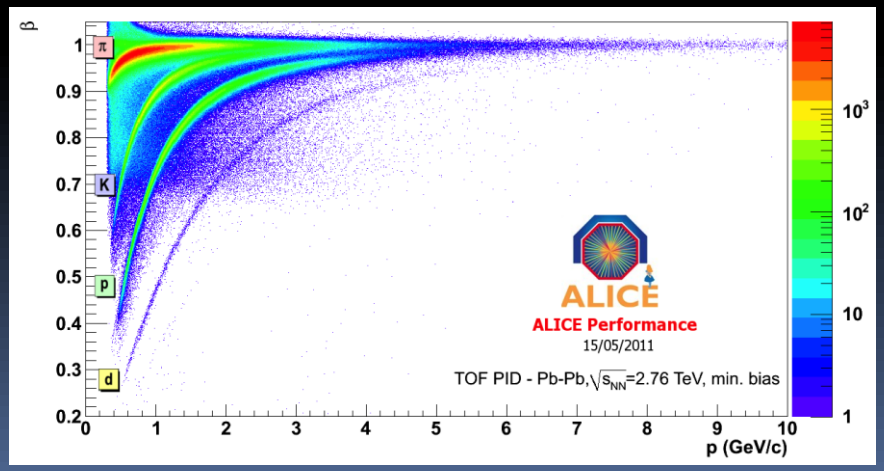
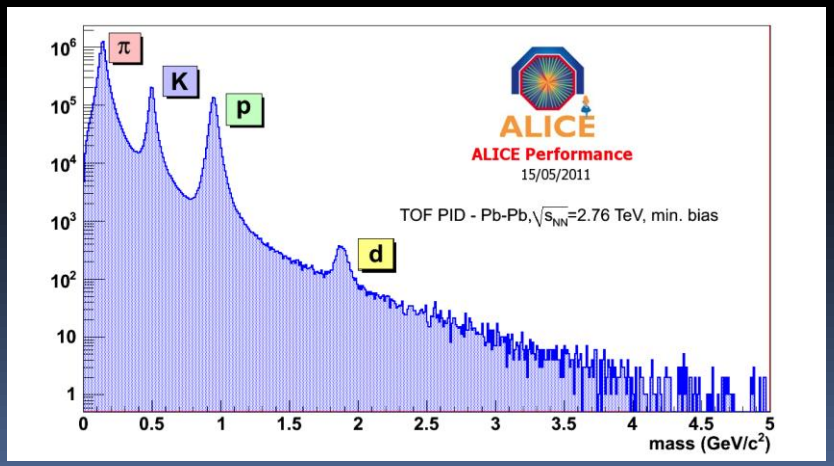




PID with the ALICE TOF

- Time Of Flight detector based on the MRPC technology (at 3.7 m, $|\eta| < 0.9$ and full ϕ)
- Intrinsic (overall – no StartTime, no tracking) resolution of 40(90-80) ps (pp-PbPb)
- Excellent charged hadron PID performance in separating π/K and K/p over a wide momentum region in the intermediate range
- Mass determined from the measured time and momentum
  - Start time of the event provided by either the ALICE T0 detector, or/and from an offline TOF algorithm





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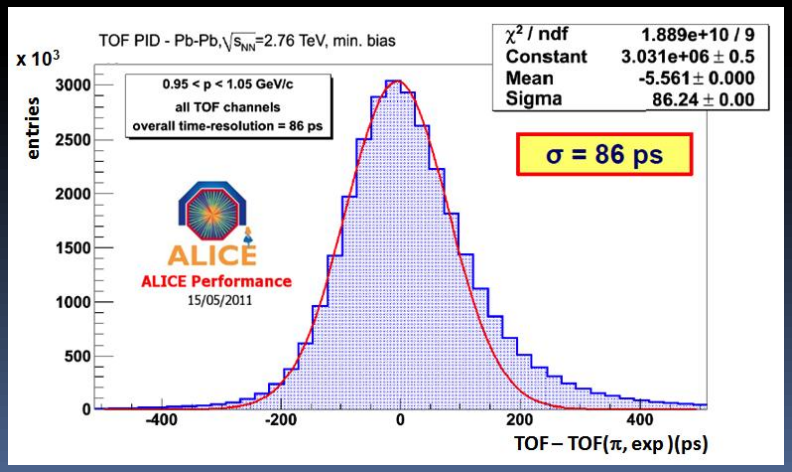
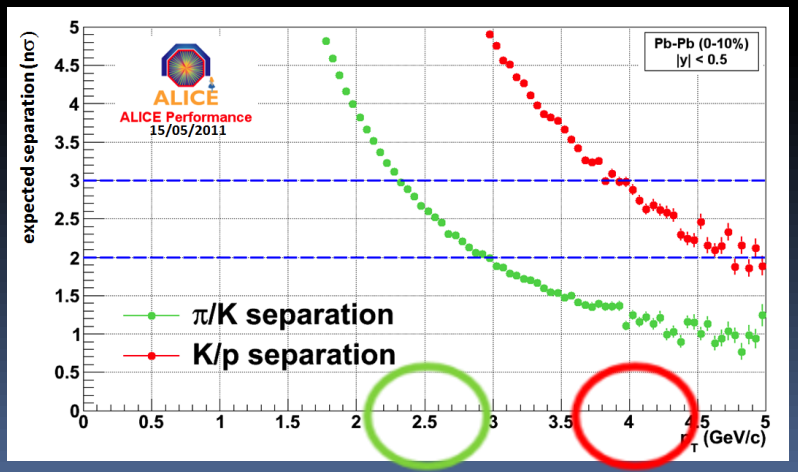
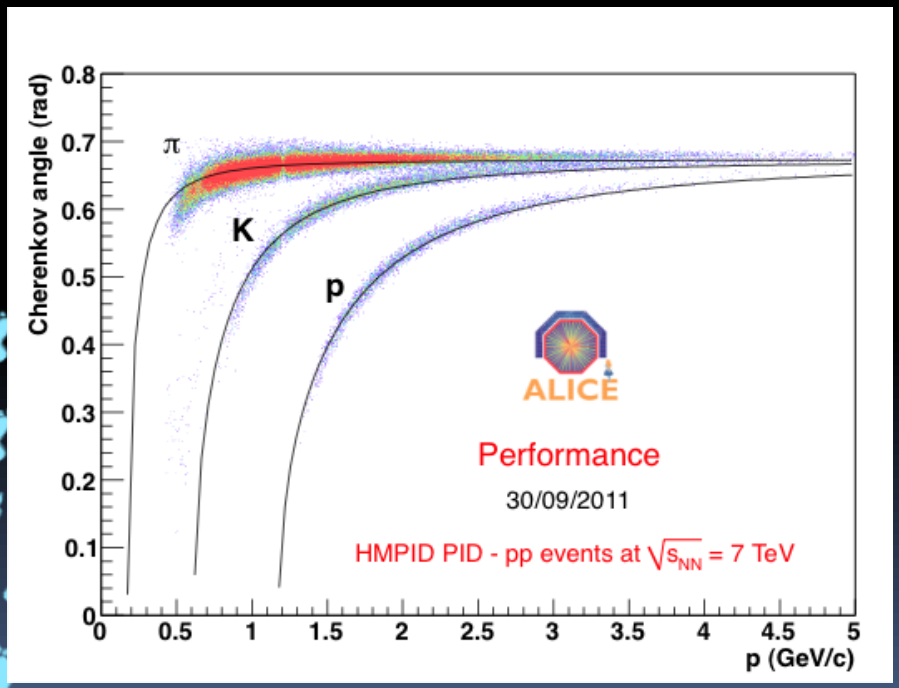


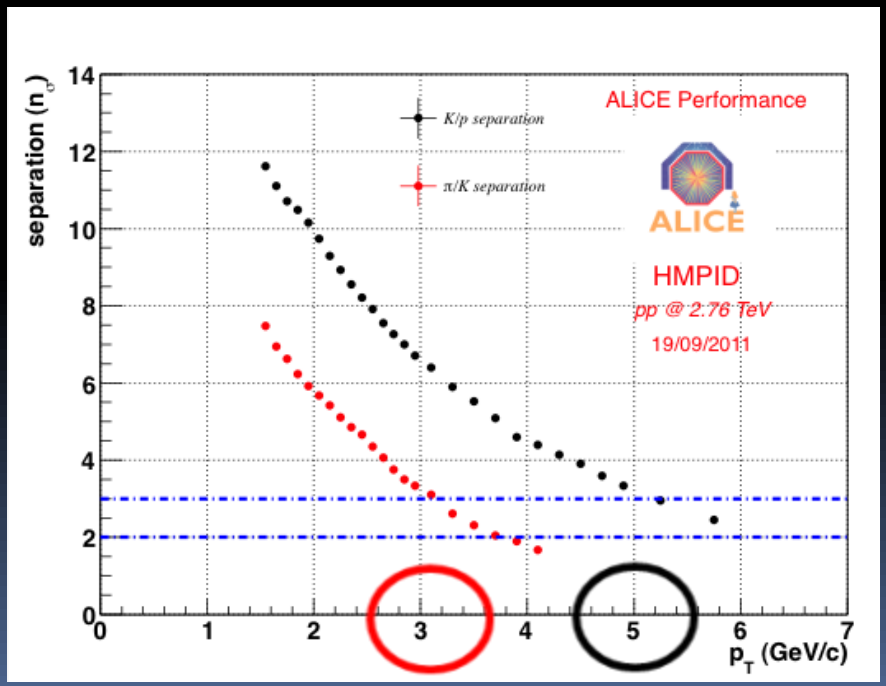


ALICE Single-Arm Detectors

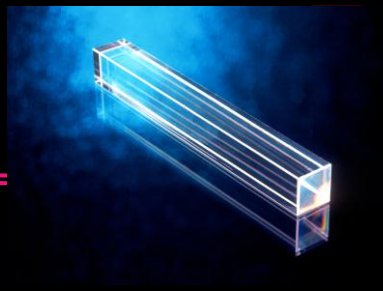
PID with the ALICE HMPID

- Single-arm proximity focusing RICH (at 4.7 m, $|\eta| < 0.6$, $1.2^{o} < \phi < 58.8^{o}$)
- Hadron ID @ higher momenta, $1<p_t<3$ GeV/c for π and K, $1<p_t<5$ GeV/c for p
- Mass determined deducing β measured from the Cherenkov angle and the momentum from TPC
- Track-to-track π/K (K/p) separation up to $p_t \sim 3$ (5) GeV/c





The ALICE Calorimeters



- PHOS
  - Homogeneous EM calorimeter (at 4.6 m, $|\eta| < 0.13$, $260^0 < \phi < 320^0$)
  - γ identification in $0 < E < 100$ GeV
  - Energy resolution

- EMCAL
  - Sampling EM calorimeter (at 4.50 m, $|\eta| < 0.7$, $80^0 < \phi < 180^0$)
  - γ identification in $0 < E < 250$ GeV
  - Energy resolution

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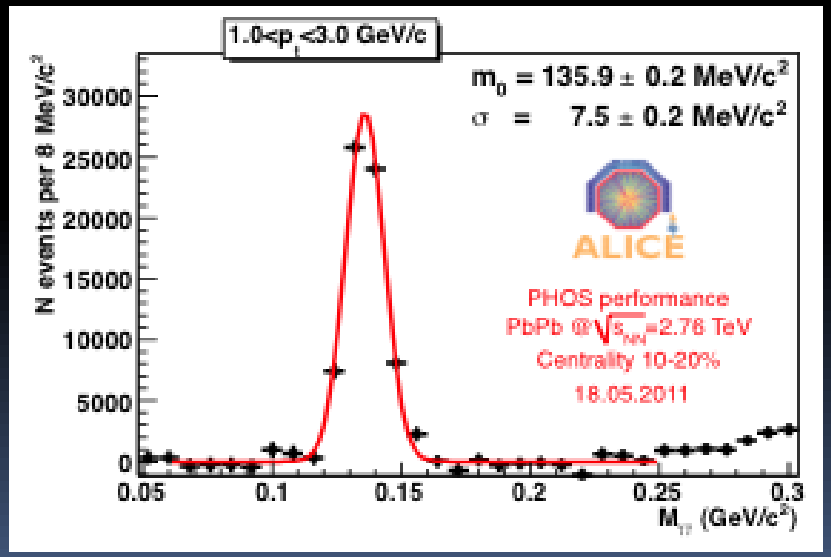

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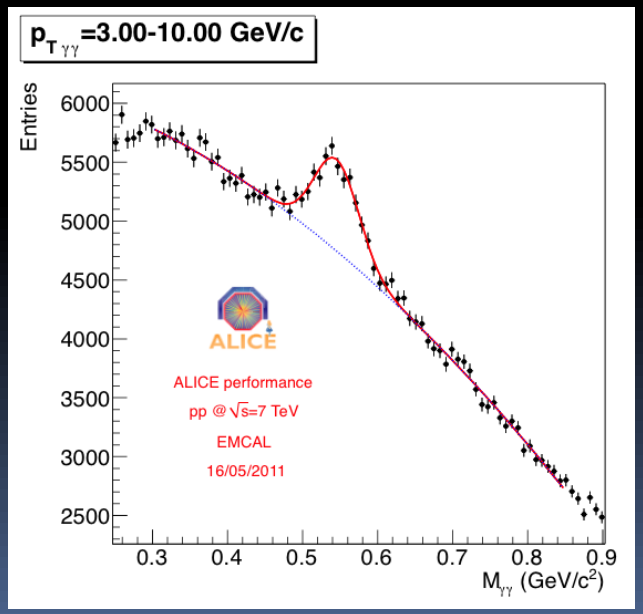
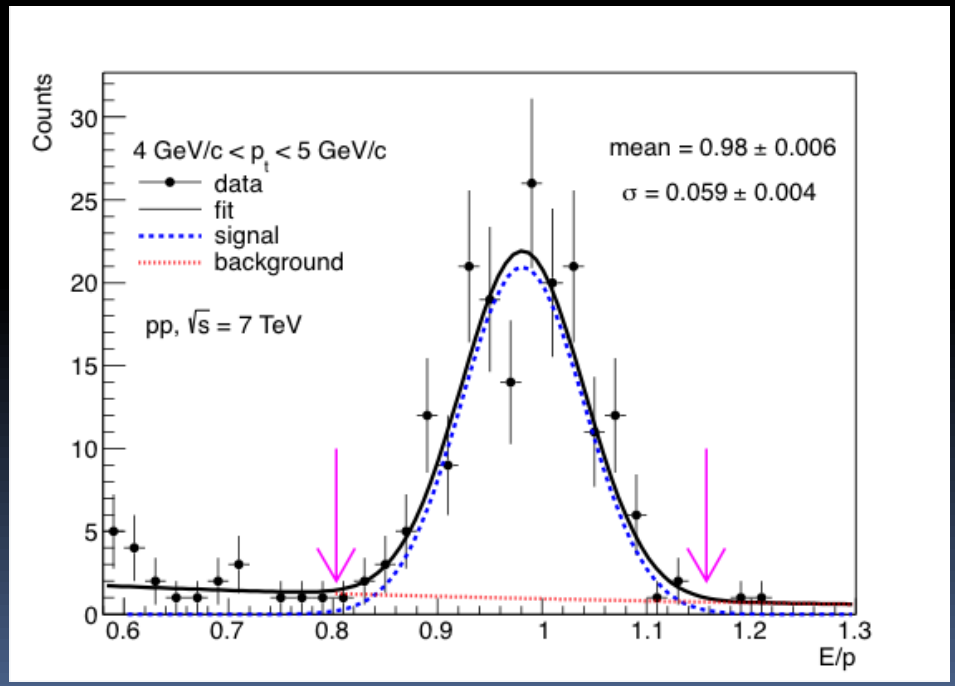


PID with the ALICE EMCAL

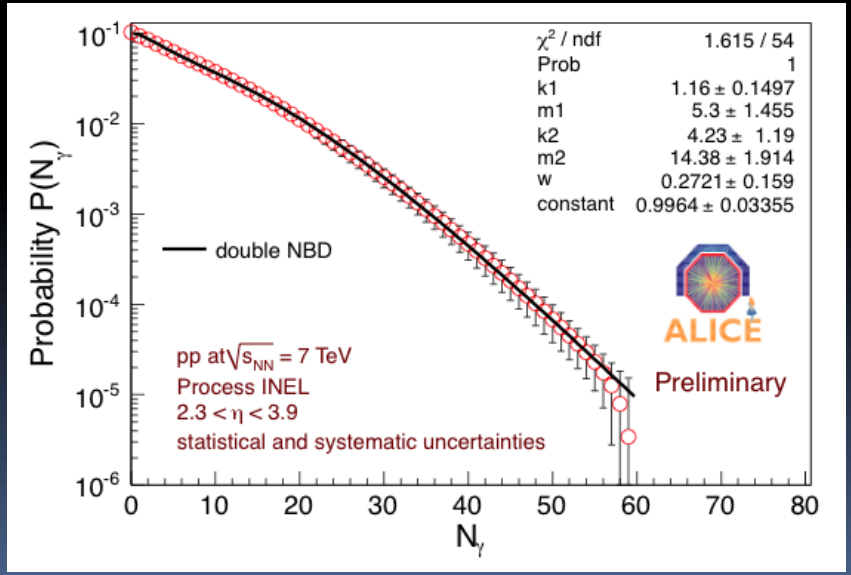
- Hadron rejection for e-ID using the E/p distribution
  - Electrons lose all their energy in the calorimeter, and have a small mass → E/p ~ 1



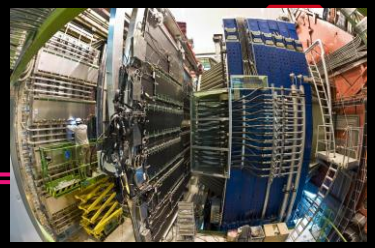
arXiv:1205.5423

The ALICE PMD

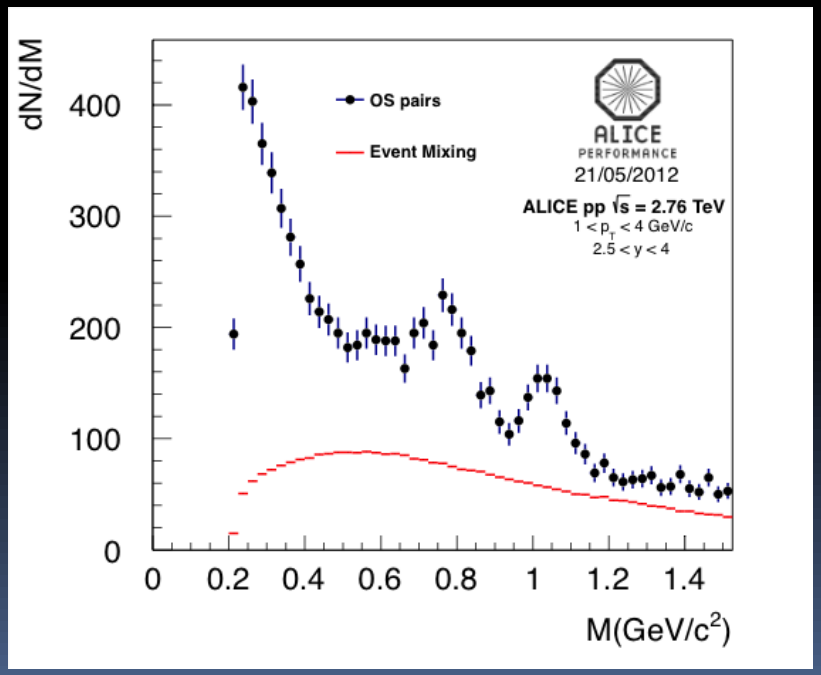
- In the forward region $2.3 < \eta < 3.7$, where the multiplicity density is too high, calorimetry cannot be used
- The PMD uses the "preshower" method
  - converter (1.5 cm thick lead, 3 Xo) sandwiched between two planes of high granularity gas proportional counters
    - 1st plane → CPV
    - 2nd plane → shower for photon identification

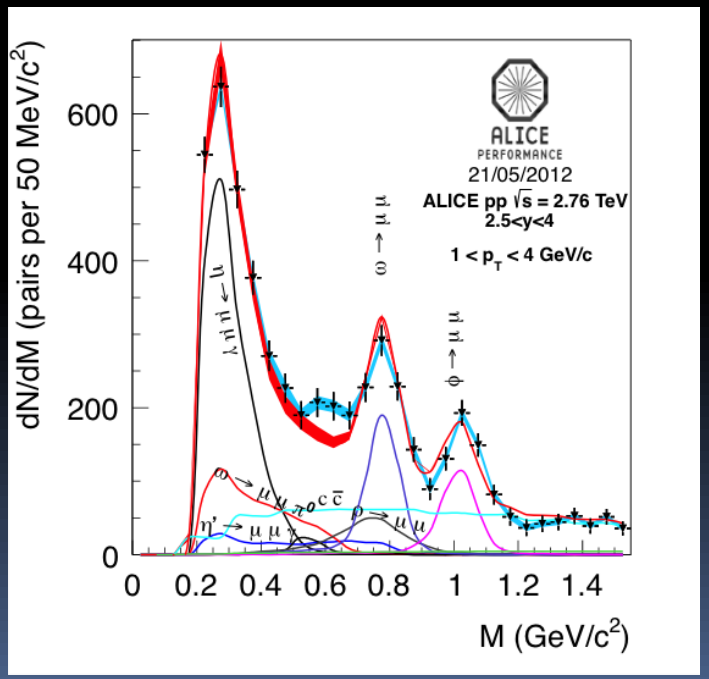


The ALICE MUON Spectrometer



- MUON Spectrometer in a dipole magnetic field (3 Tm) at $-4 < \eta < -2.5$
- Front absorber + tracking and triggering chambers + iron wall
- μ identification for $p > 4$ GeV/c
- Hadron rejection making use of the iron wall + triggering chambers

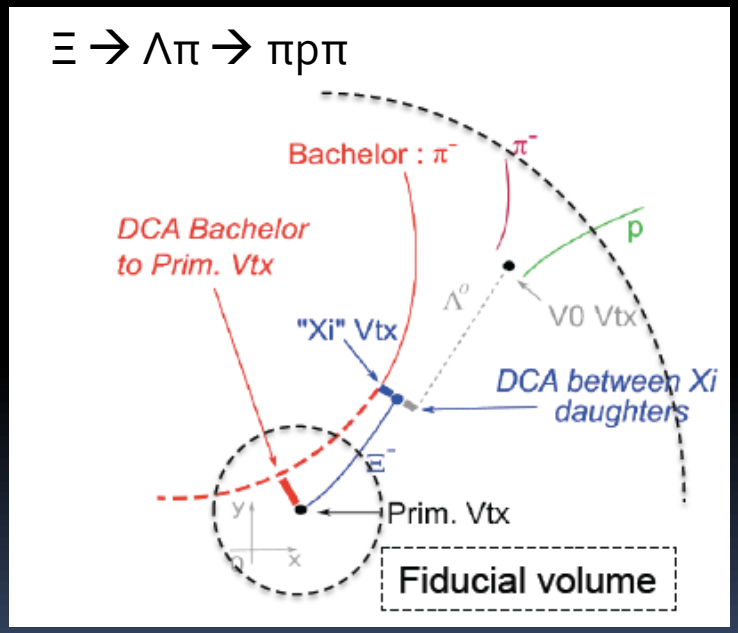


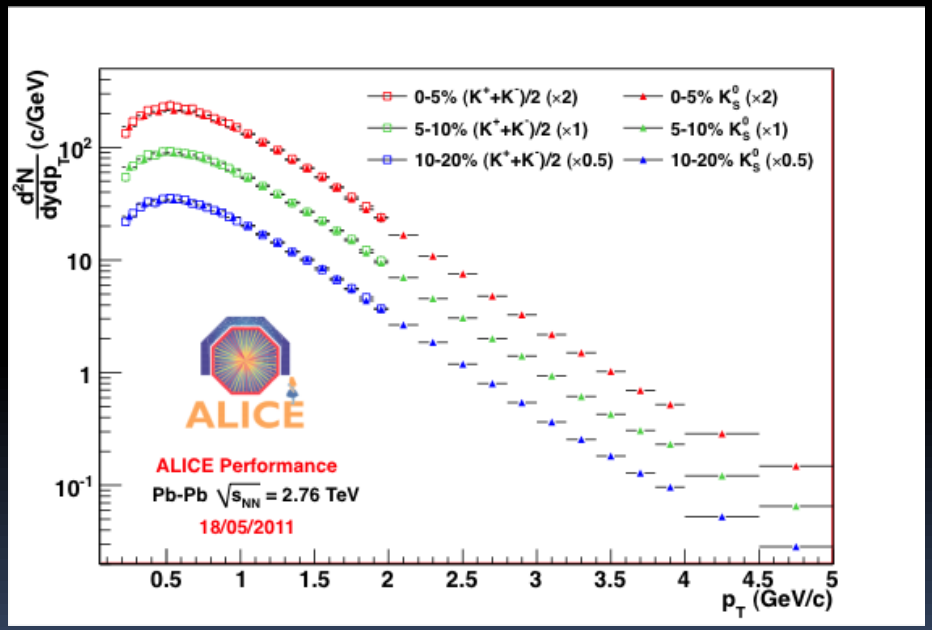


Topological PID

Topological PID

- ALICE can exploit its excellent tracking and secondary vertex reconstruction to identify cascades, V0 and kinks

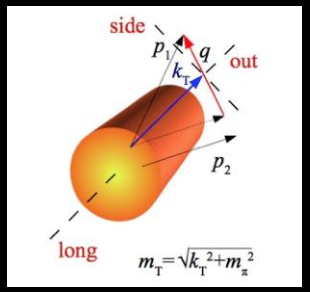




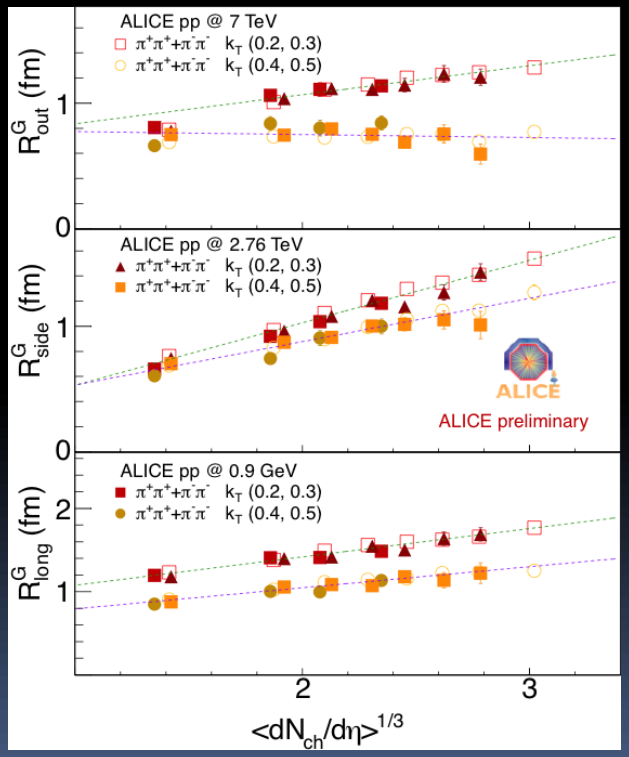
A few Physics Results with PID

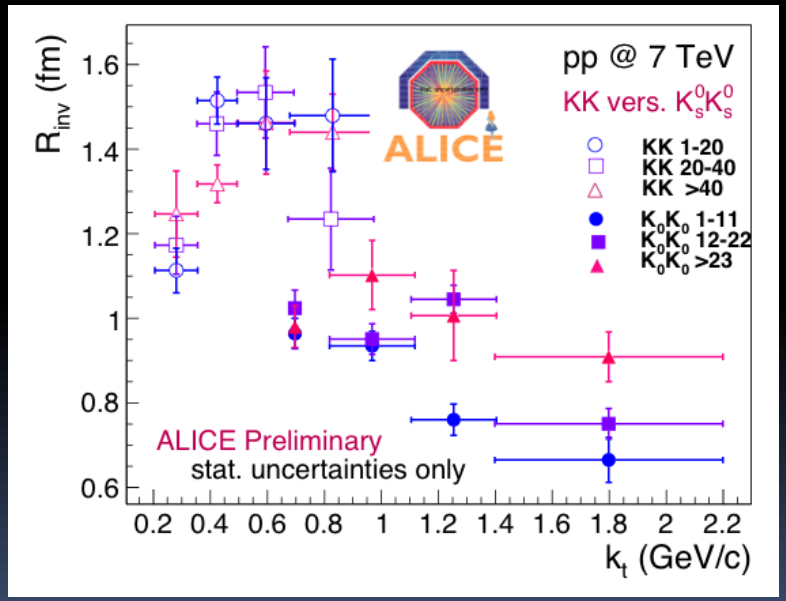
Femtoscopy

- To measure the size and the shape of the source
  - TPC (π), TPC+TOF (charged K), Topological PID (K_0)



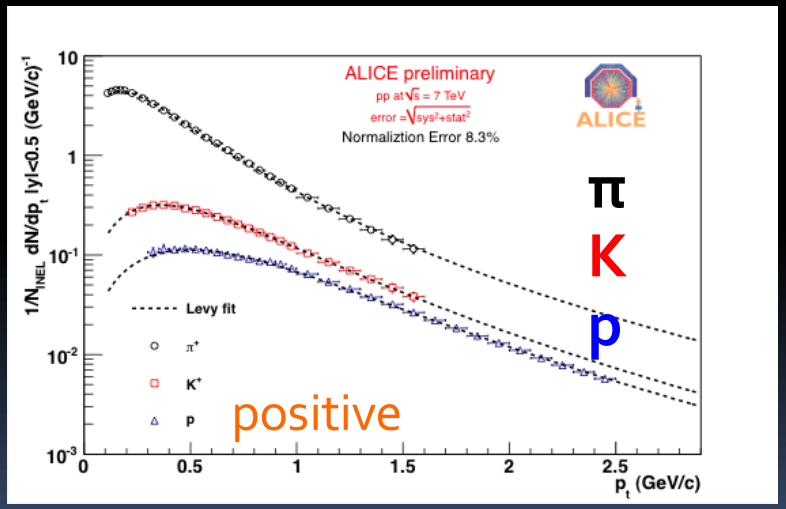
Phys. Rev. D 84, 112004 (2011)
for 0.9 and 7 TeV

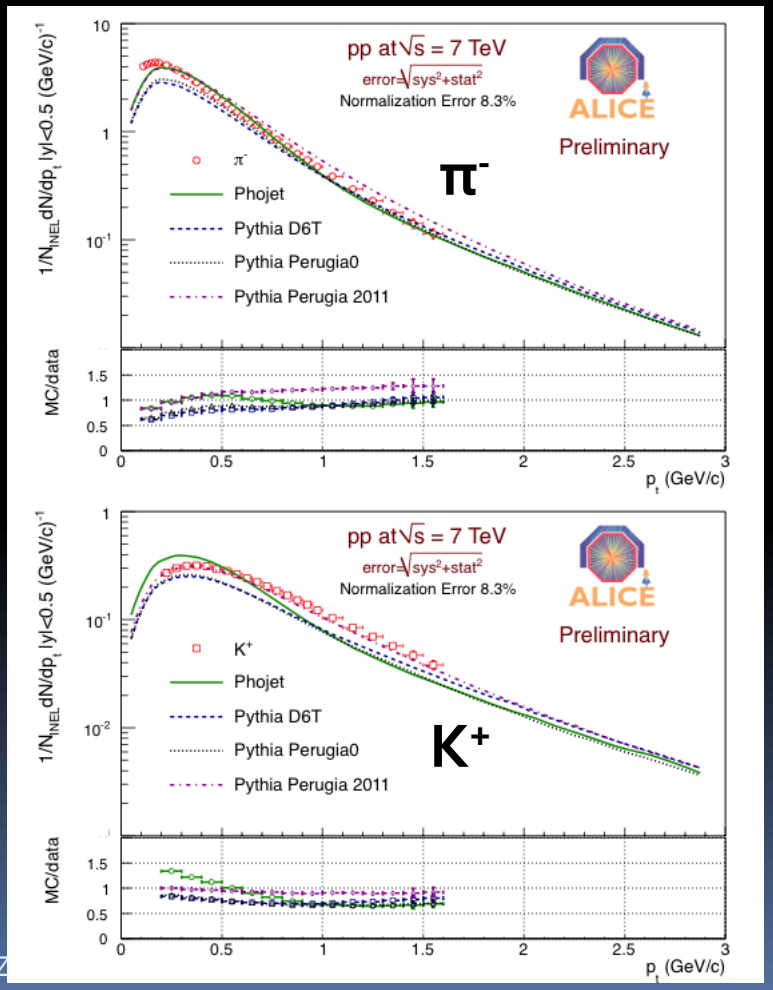




Identified Particle Spectra

- Combination of different PID techniques in different p_t regions
  - ITS, TPC, TOF
    - HMPID ongoing
  - n-σ cut + unfolding
  - Extend p_t coverage





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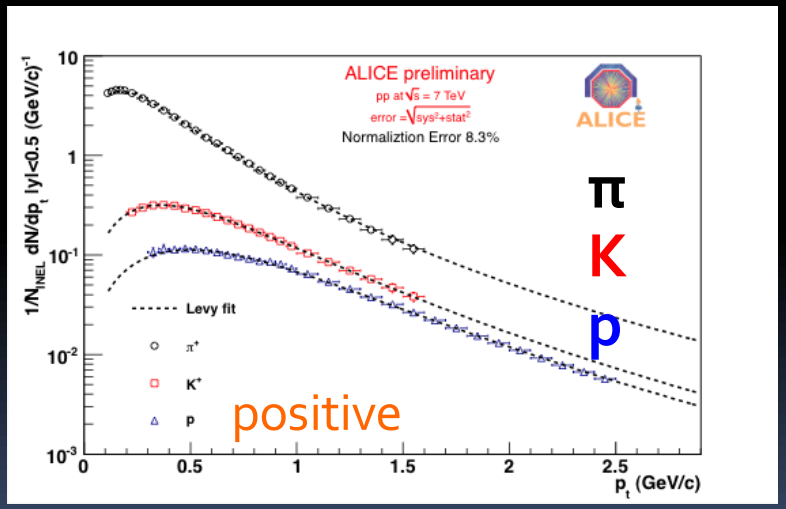
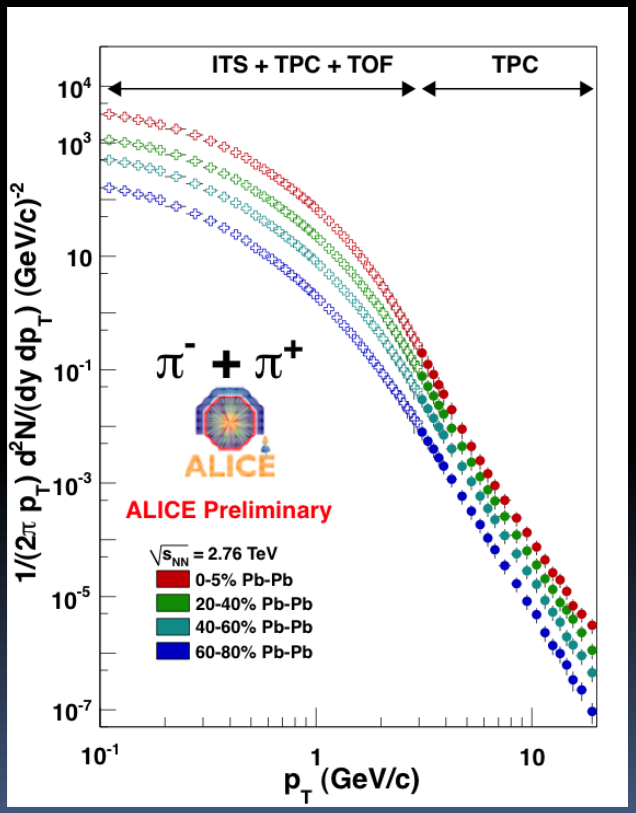
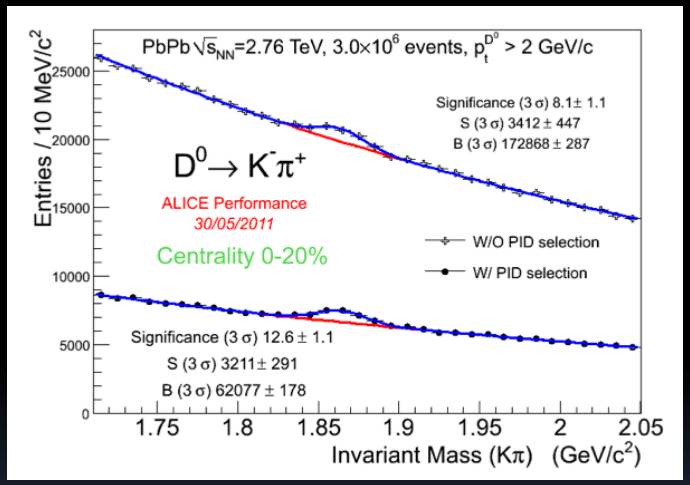


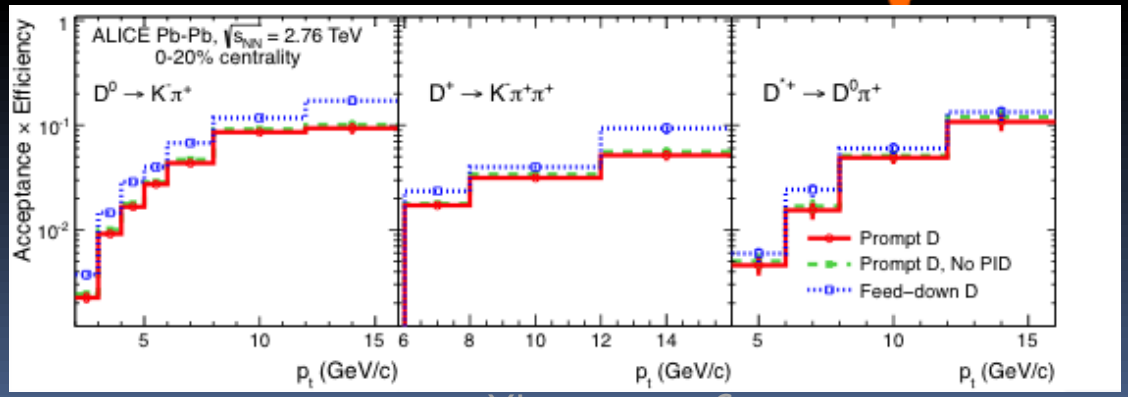


Heavy Flavour

- Open charm/beauty + quarkonia
  - TPC, TOF, TRD, EMCAL, MUON
  - PID fundamental to improve significance



Same analysis in pp and PbPb



arXiv:1203.2160v2

Heavy Flavour

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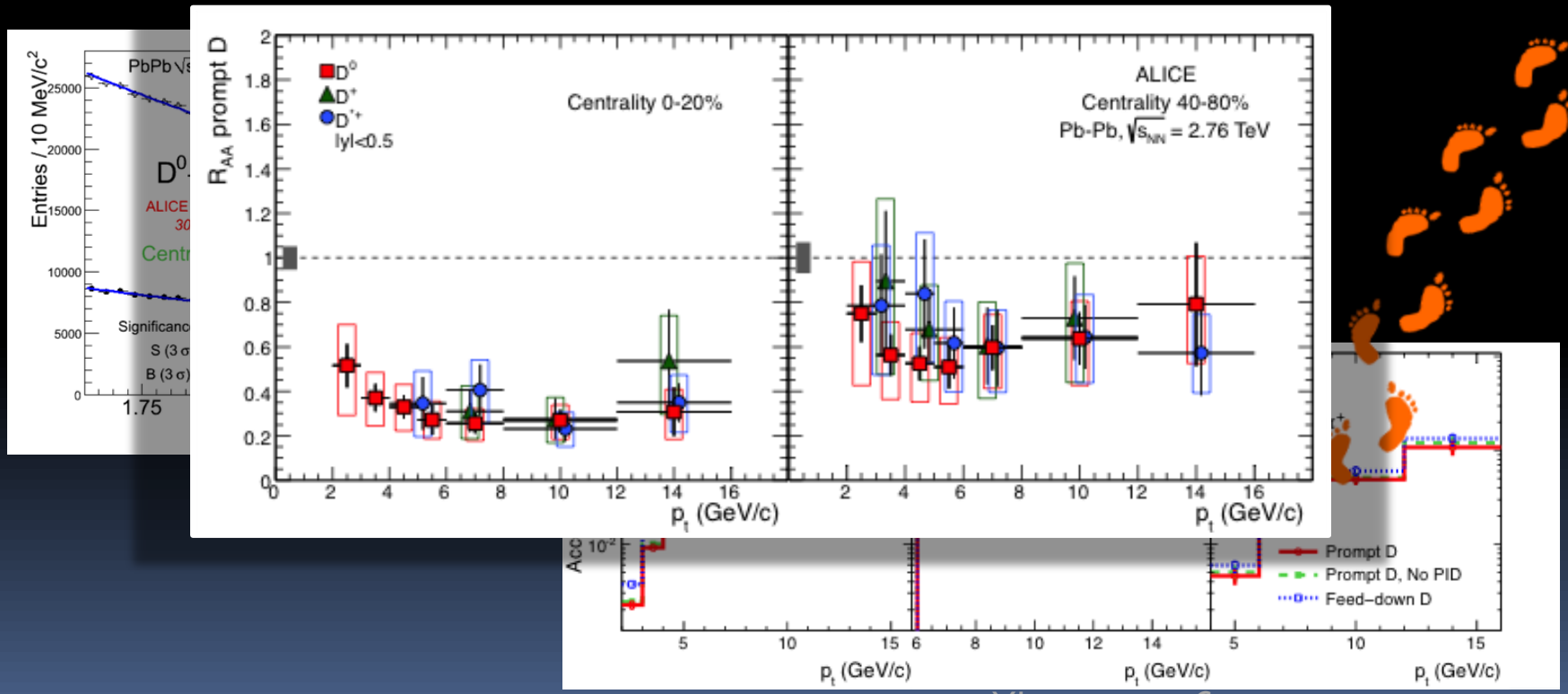
arXiv:1203.2160v2



arXiv:1203.2160v2

Heavy Flavour

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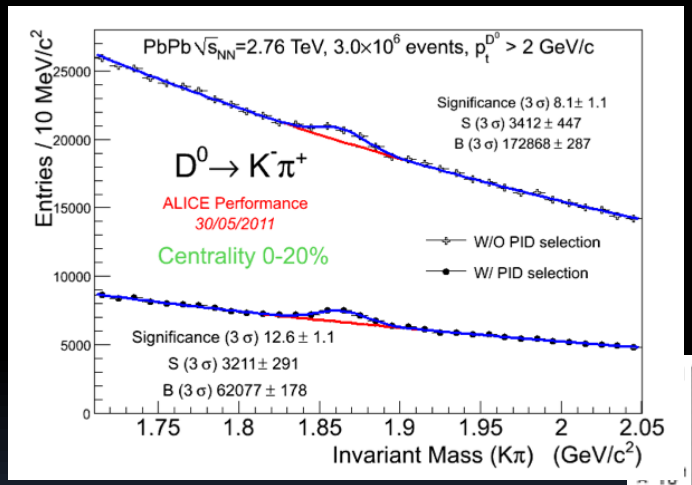
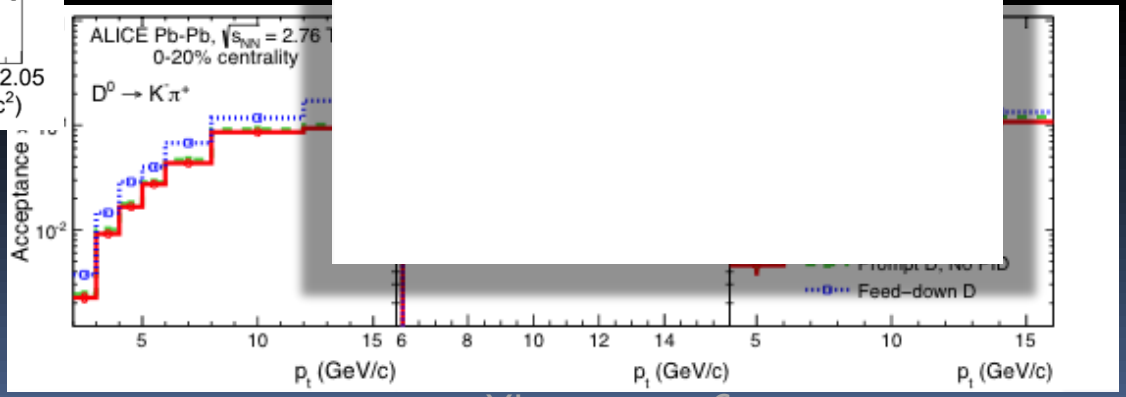
arXiv:1205.5423





arXiv:1203.2160v2

Conclusions

- ALICE is endowed with powerful PID detectors…
  - …covering different momentum ranges…
  - …using all known PID techniques…
  - …with high-level technology implementation
- The excellent ALICE PID performance makes it unique among the four main LHC experiments
  - It is an essential tool in exploring the hot dense medium created in HI collisions…
  - …and to investigate pp collisions
    - as a fundamental reference for PbPb
    - per se
    - for MC tuning

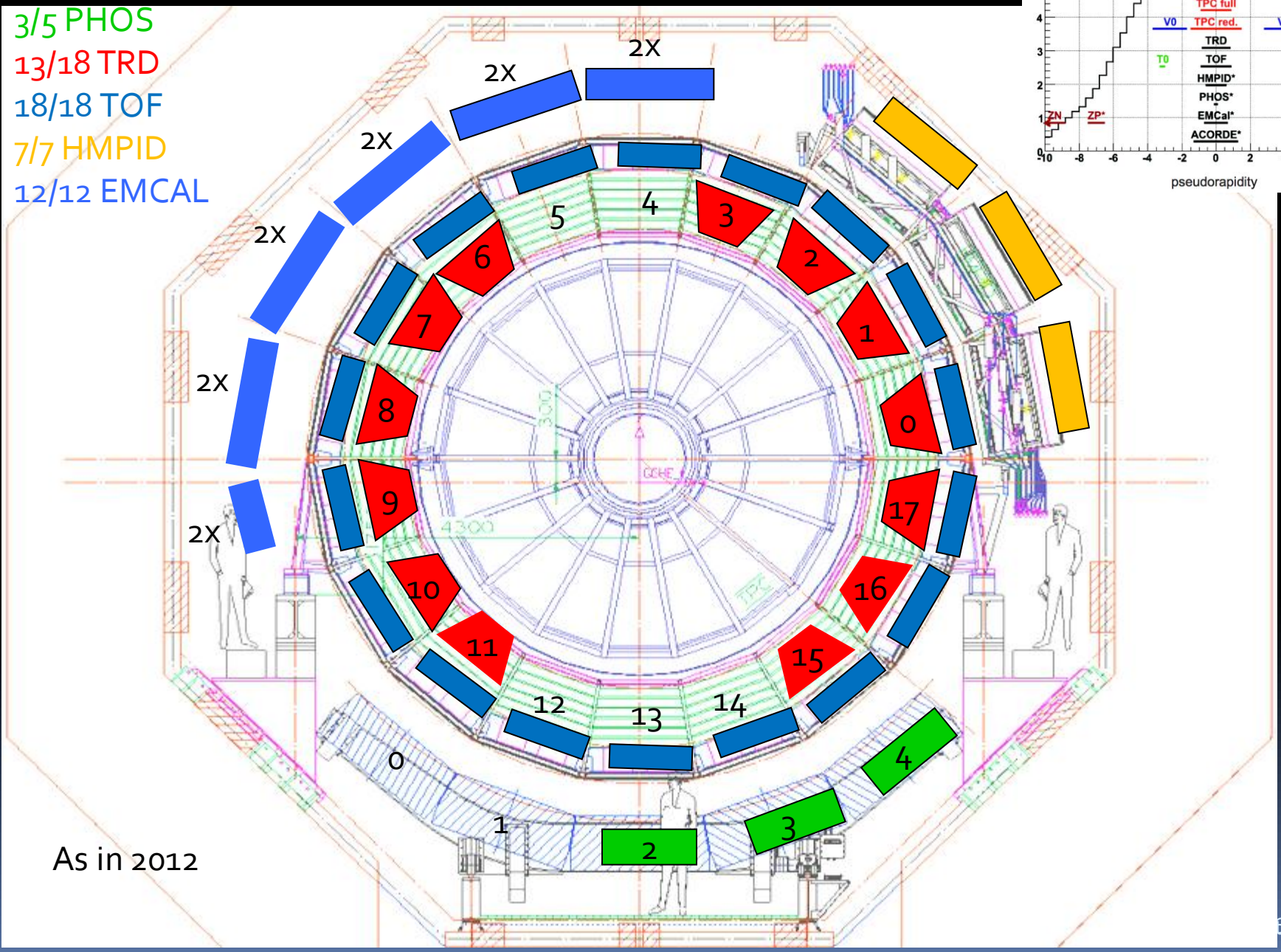
An Appropriate Citation

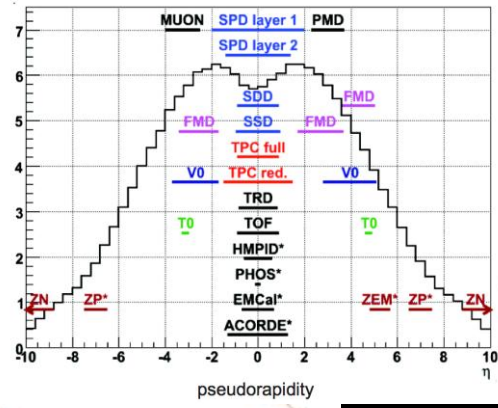
"so many out-of-the-way things had happened lately, that Alice had begun to think that very few things indeed were really impossible."
L. Carrol, Alice's Adventures In Wonderland

Backup

ALICE Configuration

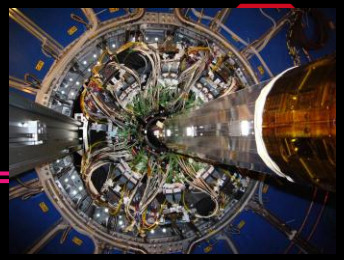
3/5 PHOS
13/18 TRD
18/18 TOF
7/7 HMPID
12/12 EMCAL

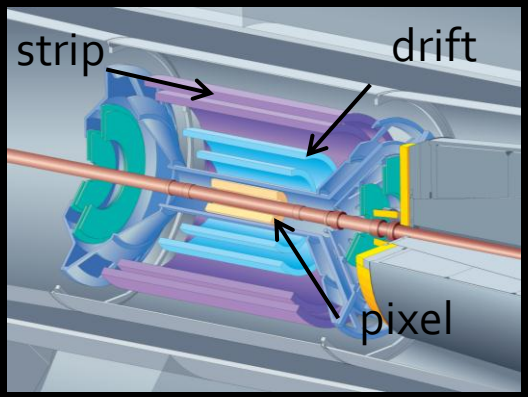




As in 2012

The ALICE ITS

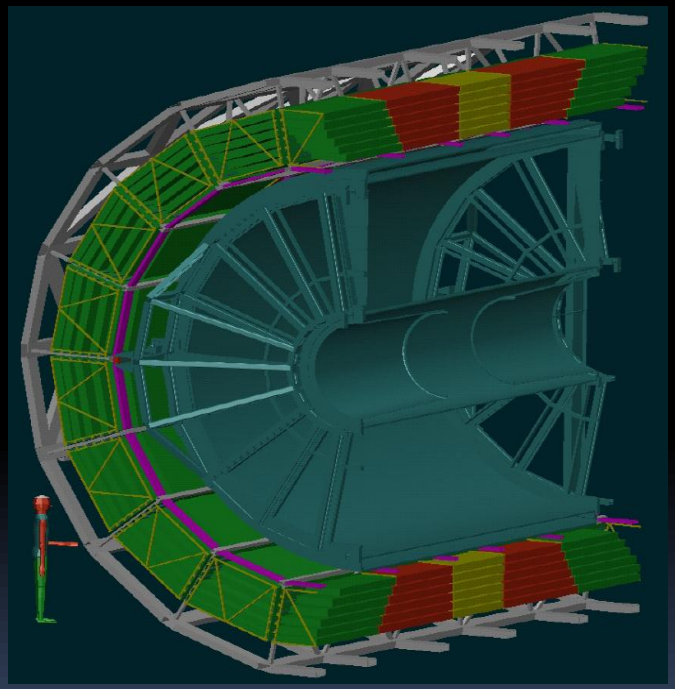




- The Inner Tracking System
  - At $|\eta| < 0.9$
  - Six layers, three technologies:
    - 2x Silicon Pixel (SPD) – 3.9/7.6 cm
    - 2x Silicon Drift (SDD) – 15/23.9 cm
    - 2x Silicon Strip (SSD) – 38/43.0 cm
  - Primary and secondary vertex reconstruction
  - Tracking + standalone reconstruction (very low momentum tracks + high momentum tracks falling in TPC dead zones)
  - PID via dE/dx from SDD and SSD analog read-out
    - In the low p_T region, down to 100 MeV for π standalone tracking

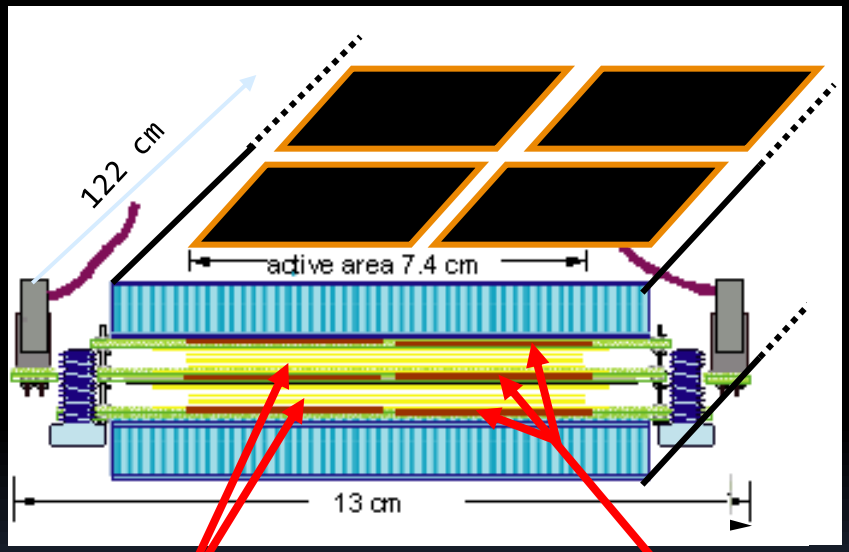
The ALICE TRD

- 6 layer Transition Radiation Detector, with 5 longitudinal stacks
  - $|\eta| < 0.9$ and full ϕ
  - Fast trigger for high-p_T particles
  - Electron ID in the momentum range $1 < p < 10$ GeV/c, with pion rejection factor ~100
  - Momentum reconstruction for p_T ~ few tens GeV/c



The ALICE TOF

- Time Of Flight detector based on the MRPC technology



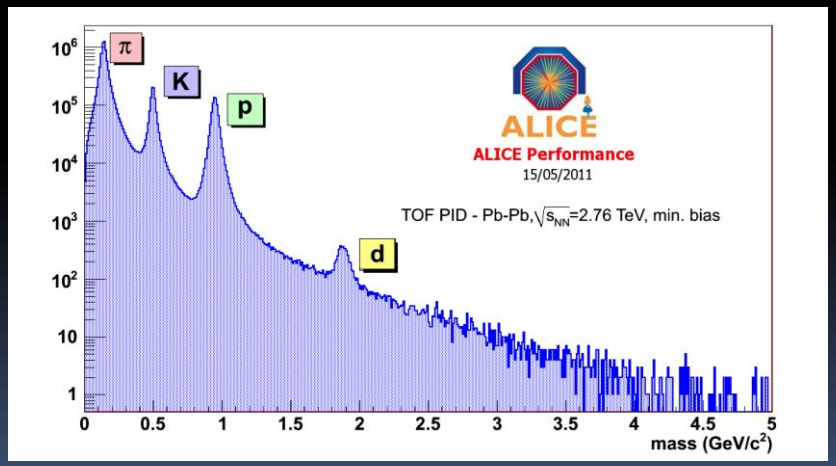
2x5 gas gaps of **250 μm**

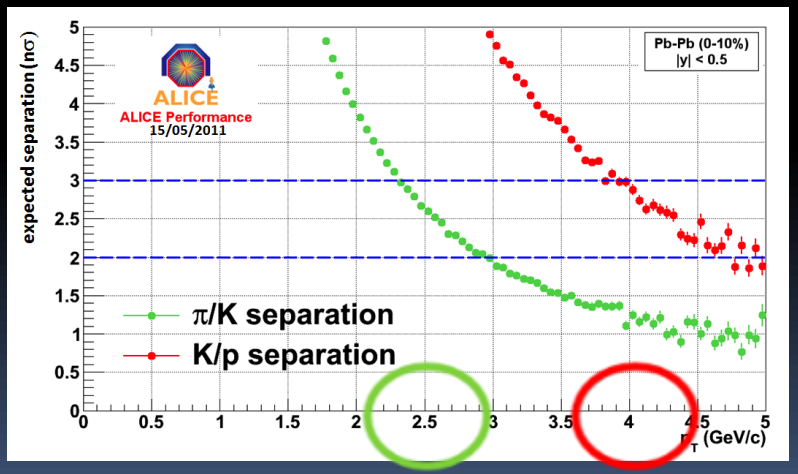
Readout pads **3.5x2.5 cm²**

- At 3.7 m from the interaction point
- $|\eta| < 0.9$ and full ϕ
- Intrinsic resolution of 40 ps
- Overall resolution of ~100 (90) ps in pp (PbPb) collisions
- Dedicated to charged hadron Identification in the intermediate momentum region

PID with the ALICE TOF

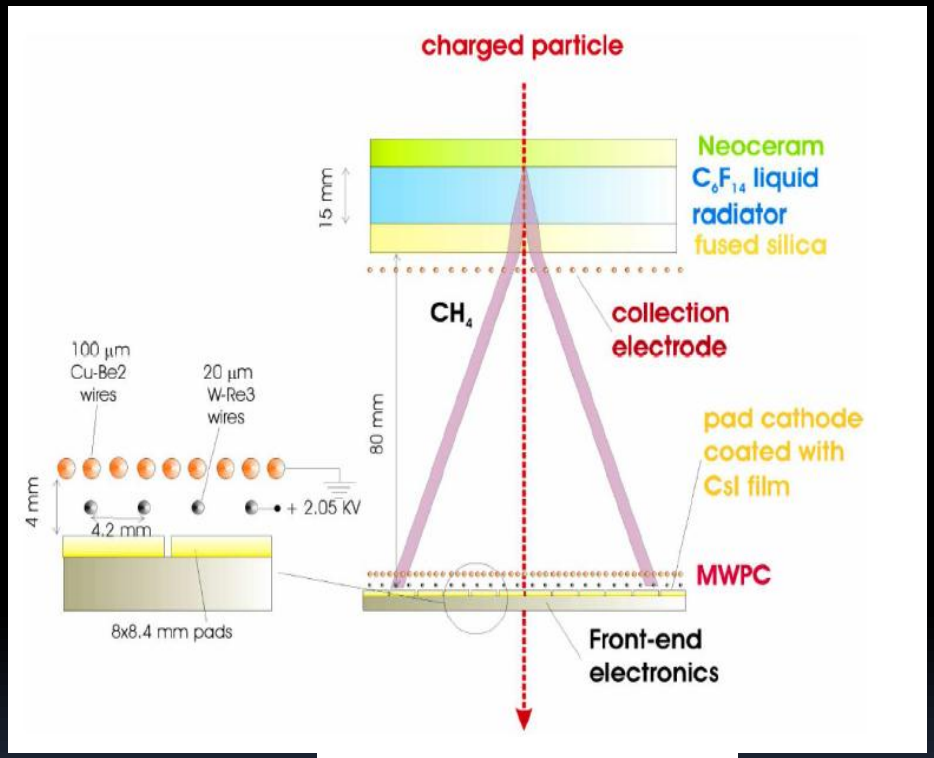
- Excellent performance in separating π/K and K/p over a wide momentum region
- Mass determined from the measured time and momentum
  - T0 of the event provided by either the ALICE T0 detector, or from an offline TOF algorithm

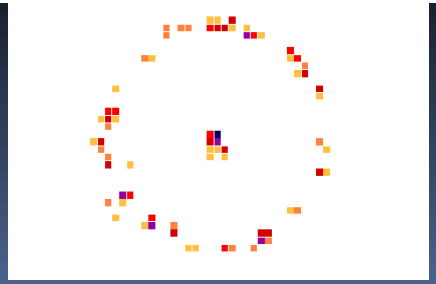




The ALICE HMPID

- Single-arm proximity focus RICH
  - 7 modules at 4.7 m, active area of 11 m^2
  - In $|\eta| < 0.6$, $1.2^0 < \phi < 58.8^0$ coverage
  - 15 mm layer of C_6F_{14} liquid radiator ($n = 1.2989$ @ $\lambda = 175$ nm, $p_{th} = 1.21$ m (GeV/c, m = mass))
  - CsI thin films deposited onto a cathode plane of MWPC (O(10^5) readout channels)
  - Hadron ID @ high momenta, $1<p_T<3$ GeV/c for π and K, $1<p_T<5$ GeV/c for p





The ALICE EMCAL

- EMCAL
  - Sampling EM calorimeter
  - 10 modules with 1152 towers of 77 layers of lead + scintillator each
  - At 4.50 cm from interaction point
  - $|\eta| < 0.7$, $80^0 < \phi < 180^0$ coverage
  - γ identification in $0 < E < 250$ GeV
  - Energy resolution

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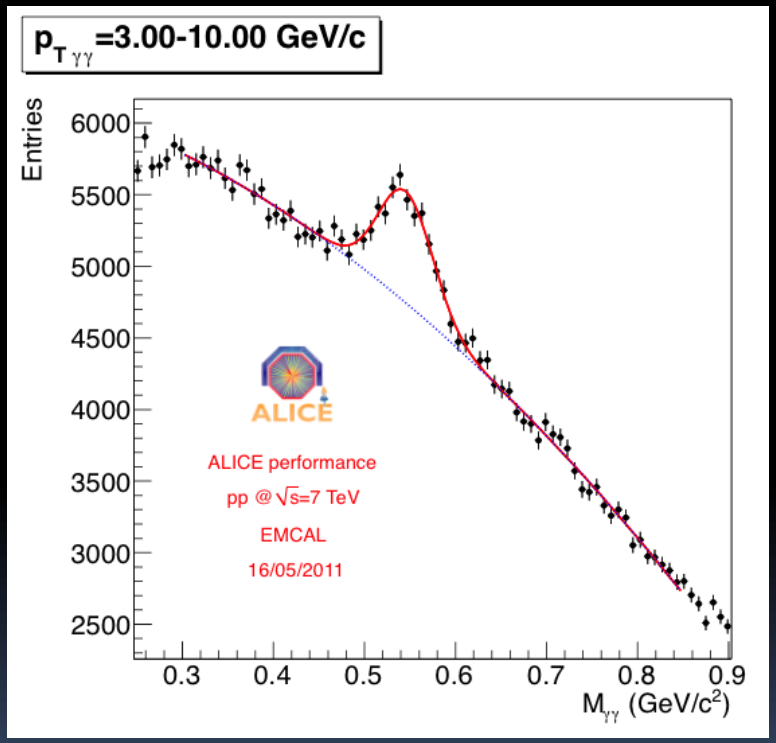
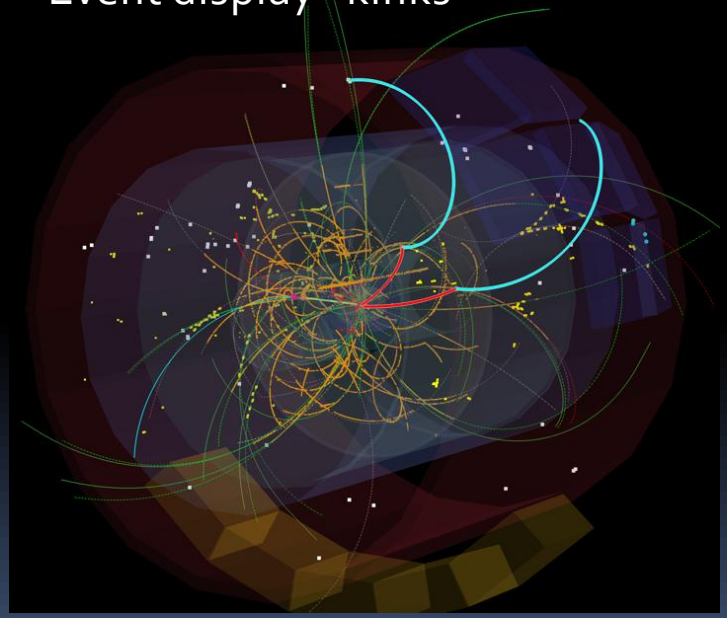


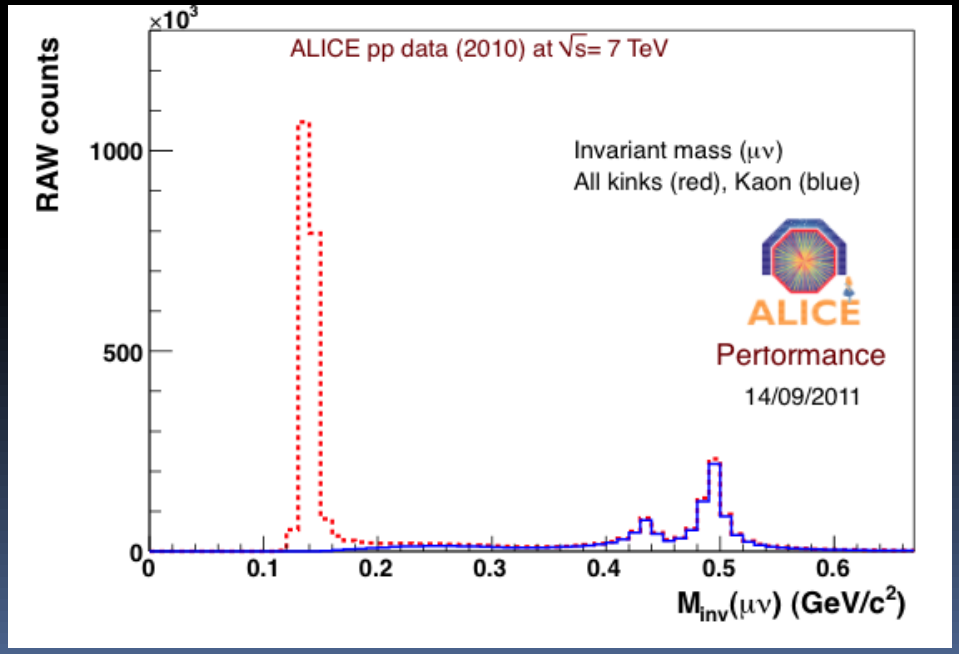
Topological PID – II

- ALICE can exploit its excellent tracking and secondary vertex reconstruction to identify cascades, V0 and kinks

Event display - kinks

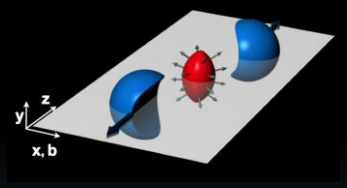
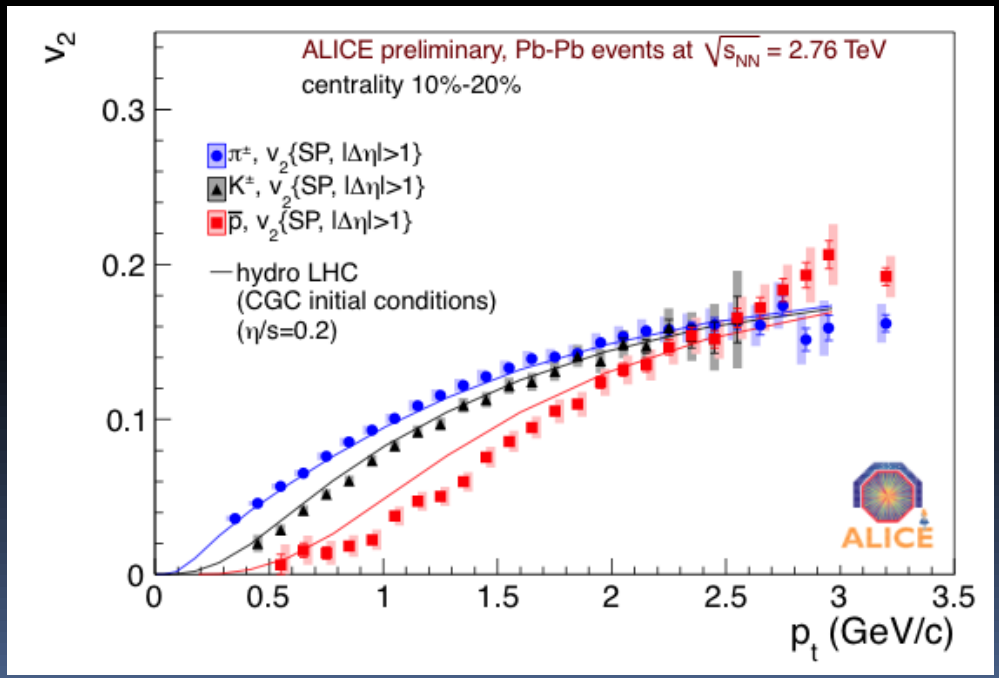


- Using decay angle, Q_t cut, M_{inv}



Elliptic Flow

- Anisotropic distribution of matter in the overlap region leads to anisotropies in the observed final particle spectra → ***elliptic flow***
- It's magnitude depends on the initial conditions, the EOS, and the system lifetime
  - TPC, TOF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