

# Energy Loss Signals in the ALICE TRD and Application in Particle Identification

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TRDs for the third Millennium

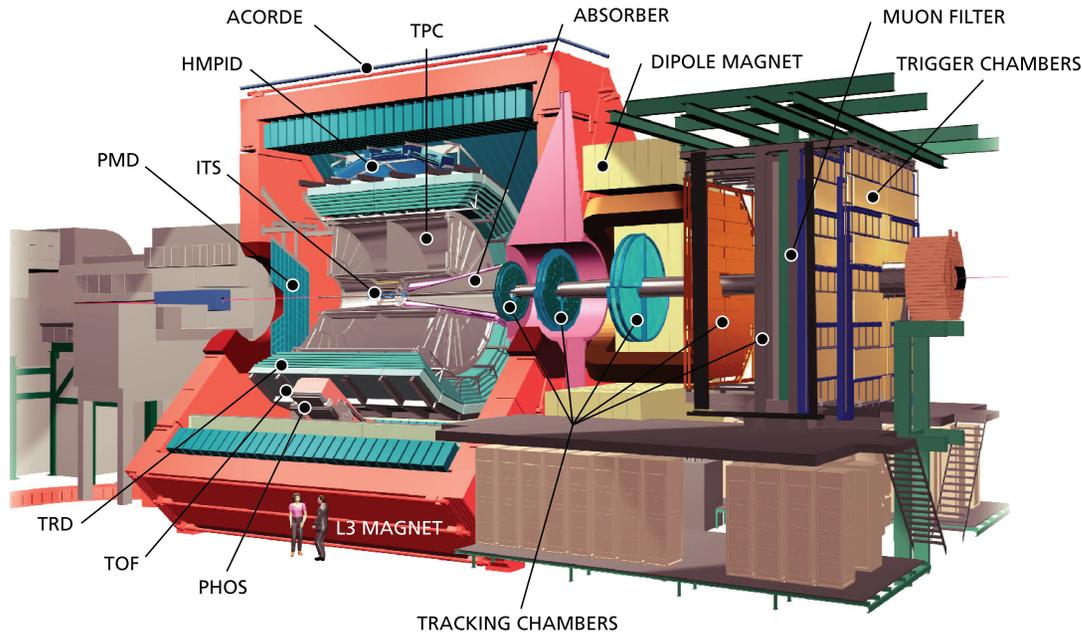
4<sup>th</sup> Workshop on Advanced Transition Radiation Detectors for Accelerator and Space Applications  
Bari, 14 September 2011



# Outline

1. The ALICE detector and its TRD
2. TRD signals from testbeam, proton-proton collisions and cosmic rays
3. Application in particle identification
4. Summary

# The ALICE Detector and its TRD



Radial position:  
2.9 – 3.7 m in 6 layers

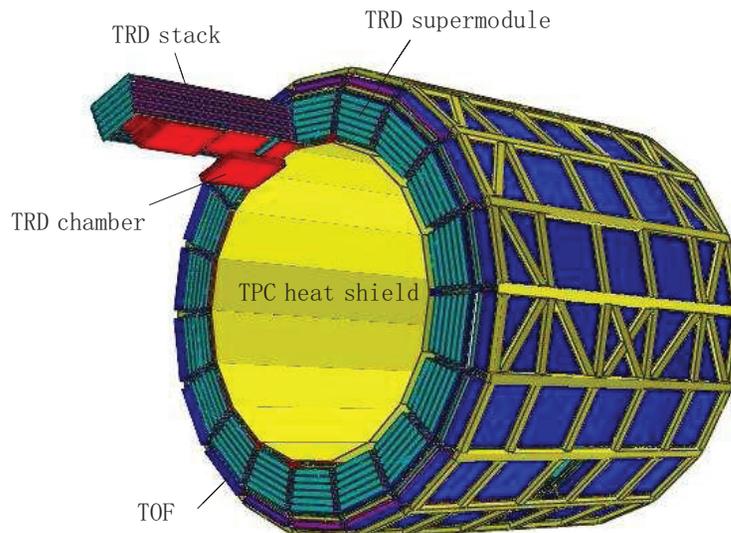
Azimuthal coverage:  
 $-60^\circ - 40^\circ$  and  $140^\circ - 240^\circ$   
in 10 supermodules (year 2011)

Polar angle coverage:  
 $45^\circ - 135^\circ$  in 5 stacks

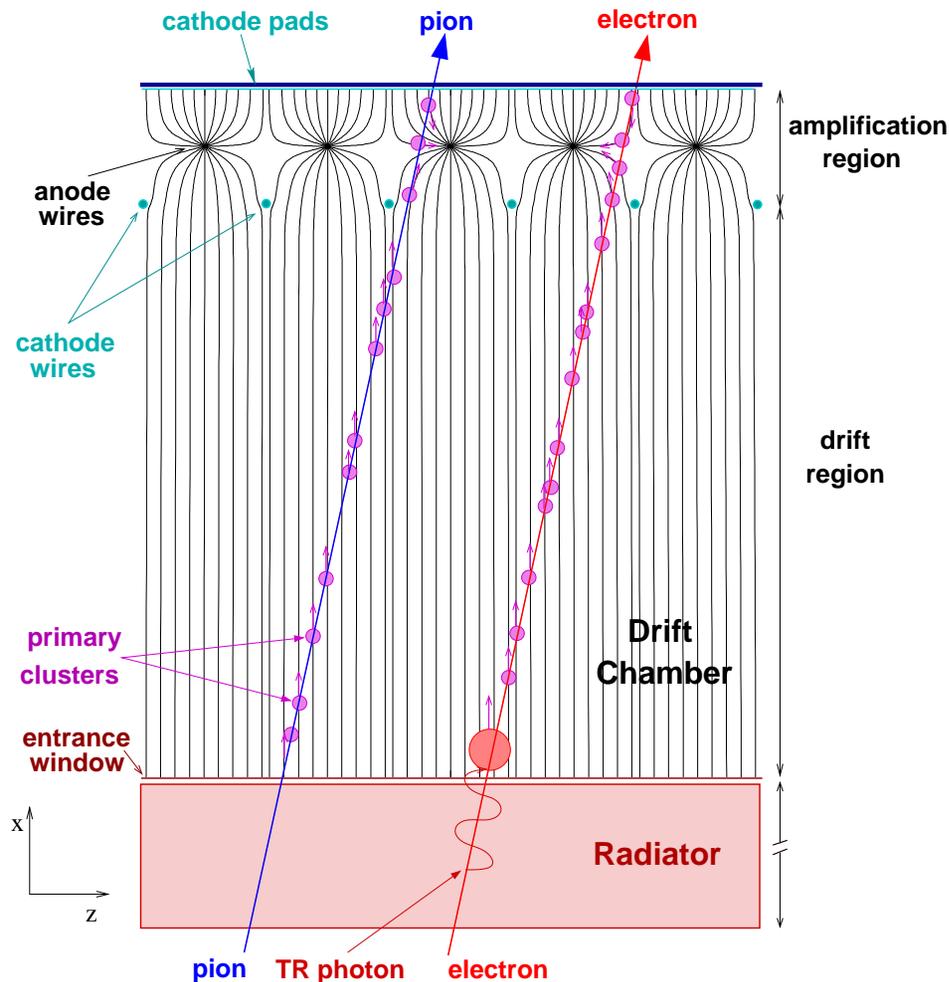
Number of chambers:  
300 (year 2011)

Goals:

- Trigger ( $\rightarrow$ J. Klein)
- Tracking
- PID using energy loss reference distributions



# Energy Loss Signals in the TRD Chamber



Radiator:  
fibres/foam sandwich, thickness 4.8 cm

Drift Chamber:  
MWPC, Xe/CO<sub>2</sub> (85%/15%)

Depth of drift/amplification region:  
3 cm/0.7 cm

Area of largest chamber:  
117 × 147 cm<sup>2</sup>

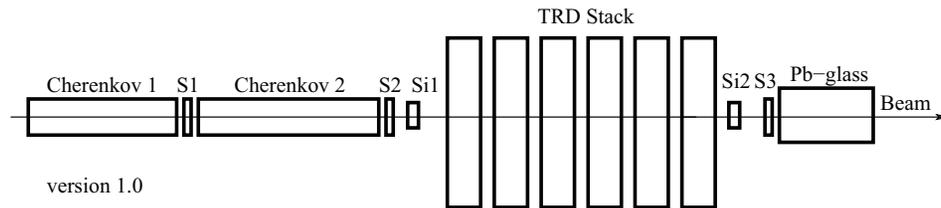
Number of readout pads:  
144 in  $r\phi$ , 12 or 16 in  $z$

Typical pad size:  
0.7 × 8.8 cm<sup>2</sup>

Spatial information in radial direction converted from temporal information via drift velocity (**conceptually a mini TPC**).

**TRD signal (energy loss per unit path length) calculated as sum of drift charge over all time-bins corrected for incident angle.**

# TRD Signals from Testbeam



Beam:  
 $\pi$ , e @CERN PS

Momentum:  
1.0–10.0 GeV/c

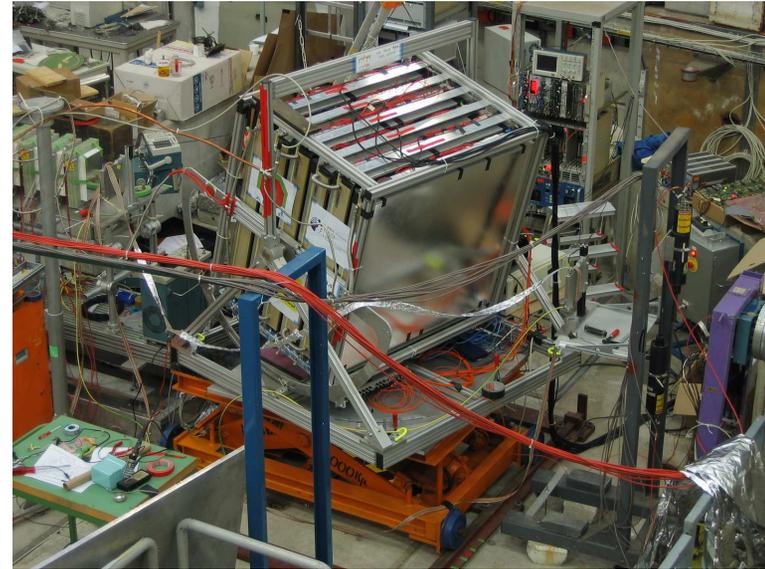
Trigger:  
scintillator S1–3

Tracking:  
silicon strip Si1–2

PID:  
Cherenkov1–2, Pb-glass

TRD chamber:  
real-size for dE/dx+TR,  
prototype (radiator detached) for dE/dx

Reference: [[ALI03](#)], [[ALI05](#)], [[Ems10](#)]

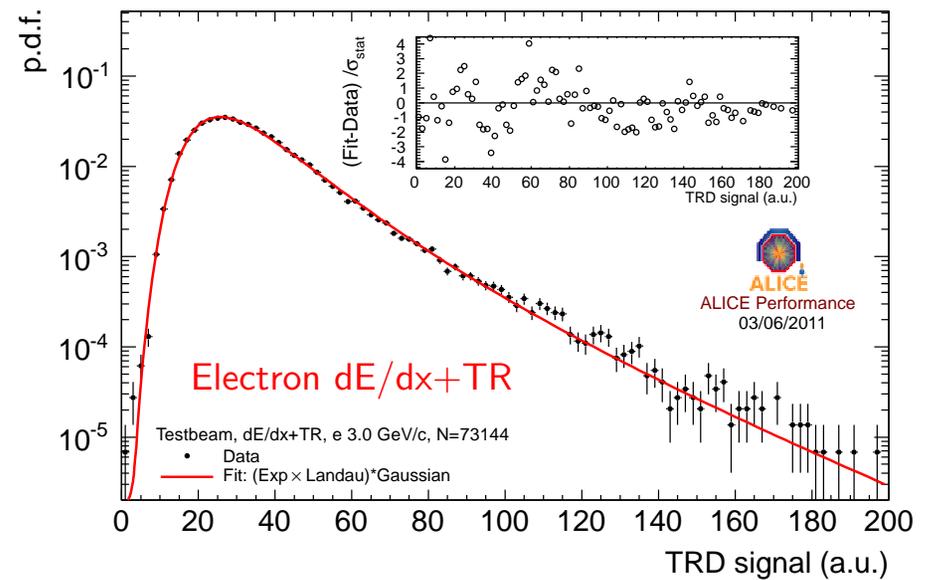
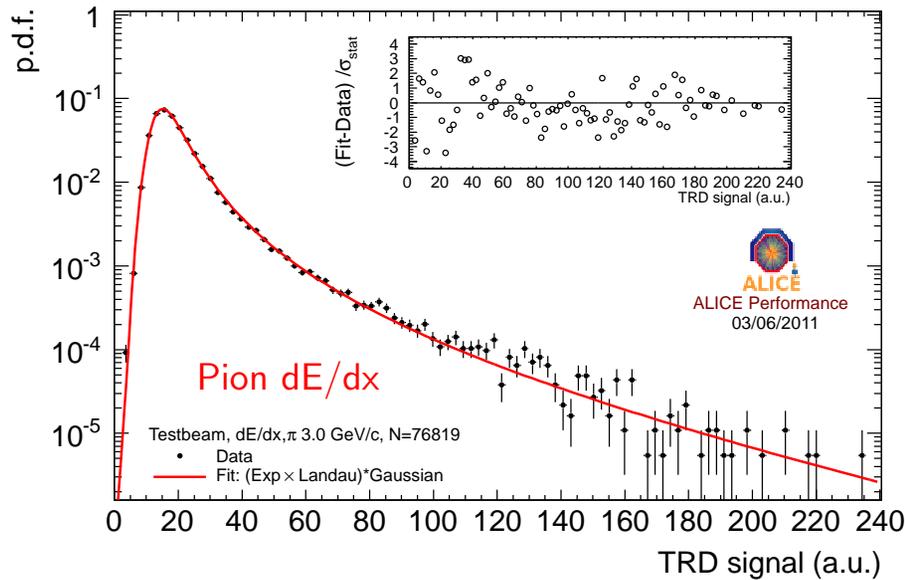


# Fit to Distribution of TRD Signals

Instead of Landau\*Gaussian, we use

(Exponential  $\times$  Landau) \* Gaussian, i.e.  $\text{Landau}(x) \rightarrow e^{-\kappa x} \text{Landau}(x)$ ,

to fit both pure dE/dx and dE/dx+TR signals.



Advantages of fitting:

- overcome statistical fluctuations,
- the distribution can be fully reconstructed with fitted parameters.

# TRD Signals in Proton-Proton Collisions

Particle:

$\rho$ ,  $\pi$ ,  $e$

B-field:

0.5 T

Trigger:

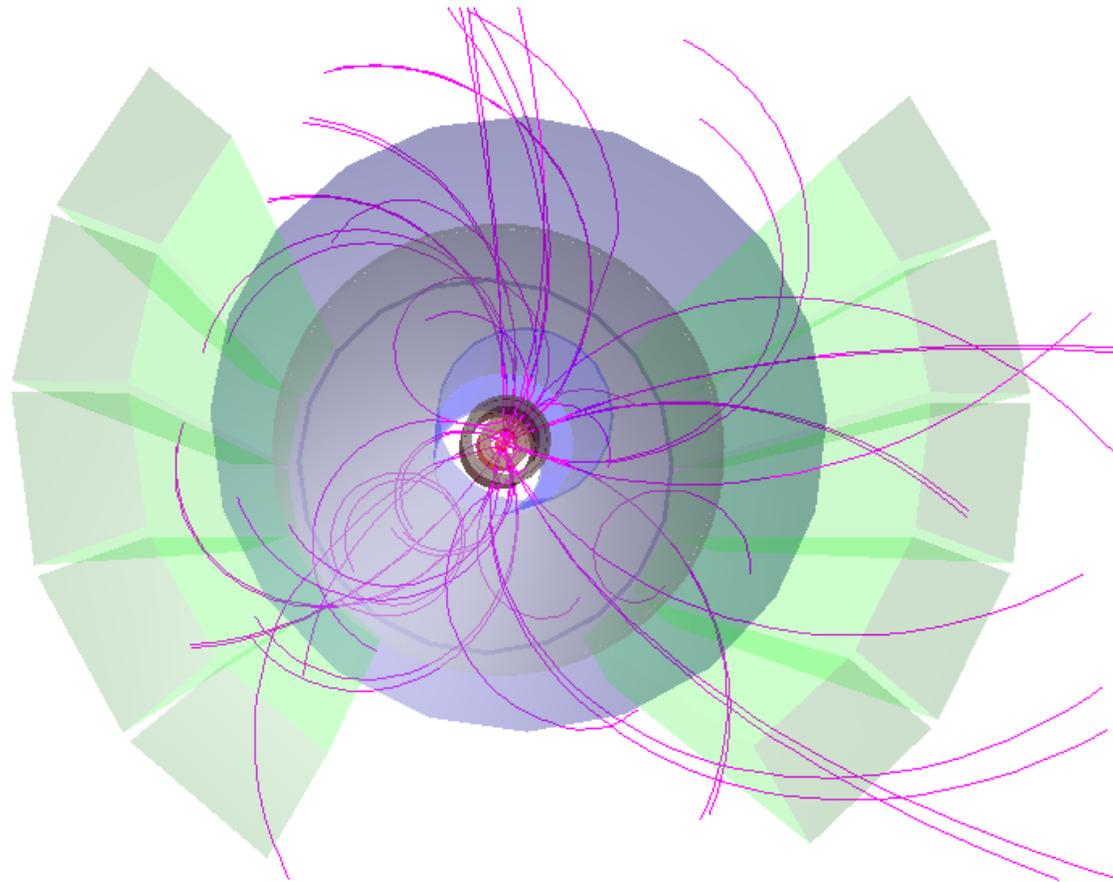
minimum bias

Tracking:

ITS, TPC, TRD

PID:

TPC, TOF, decay of  $\gamma$   $\Lambda$   $K_0$



# TRD Signals from Cosmic Rays

Particle:

$\mu$

B-field:

0.5 T,

0.1 T for detection of MIP

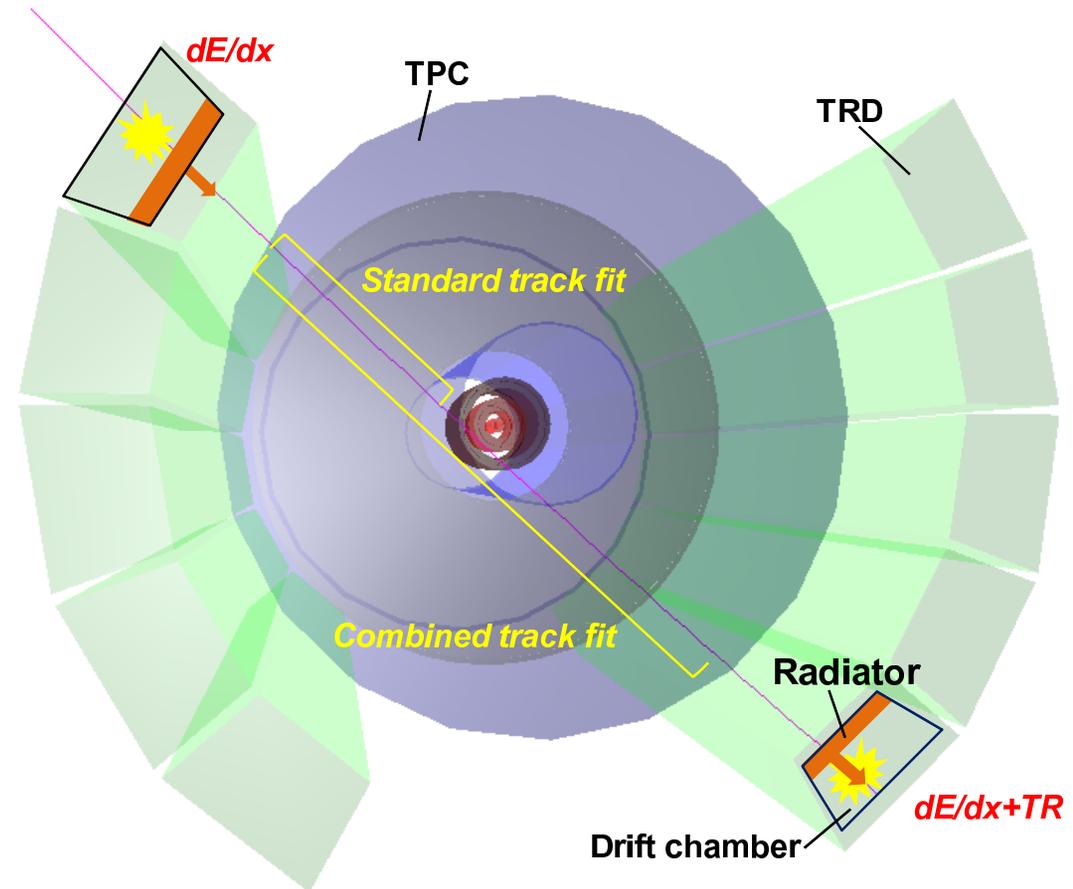
Trigger:

TOF+TRD cosmic trigger

Tracking:

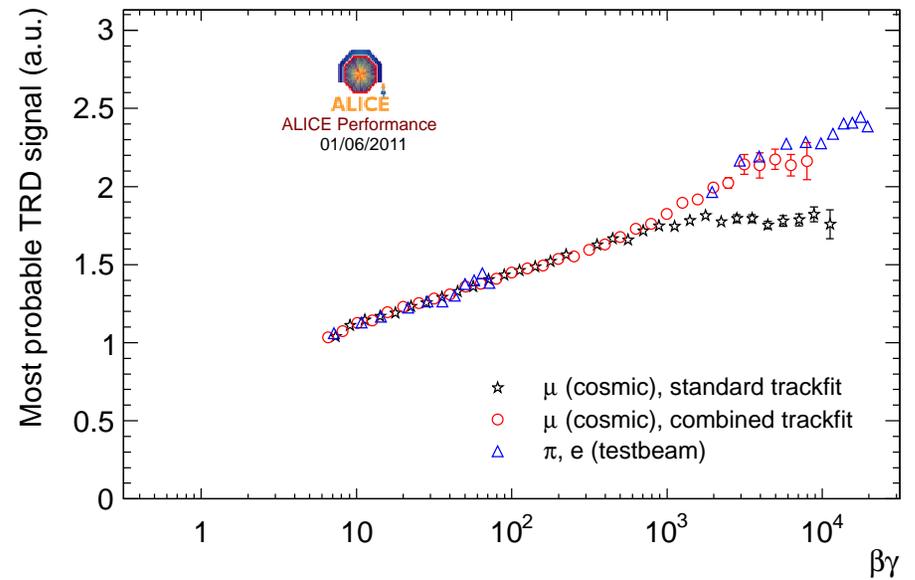
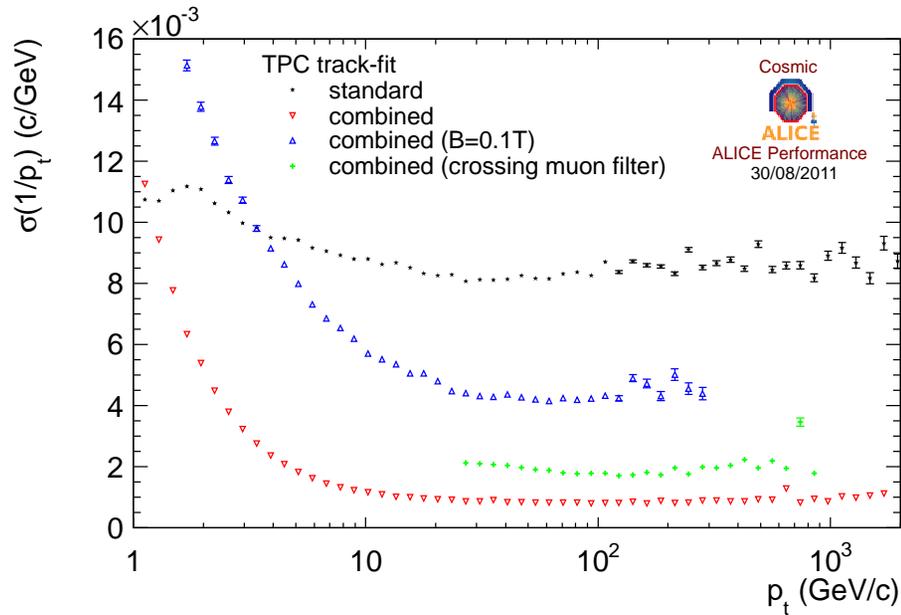
TPC combined track fit,

TPC standard track fit + TRD  
for low momentum track



- No TRD signal in  $10^2 < \beta\gamma < 10^3$  is measured in testbeam and proton-proton collisions. Kinematically cosmic muons fill in this gap.
- Pure  $dE/dx$  signal is measured for TRD in the ALICE cavern with rays traversing the TRD drift section **before** the radiator.
- $dE/dx+TR$  signal is measured with rays traversing the TRD drift section **after** the radiator.

# TRD Signals from Cosmic Rays

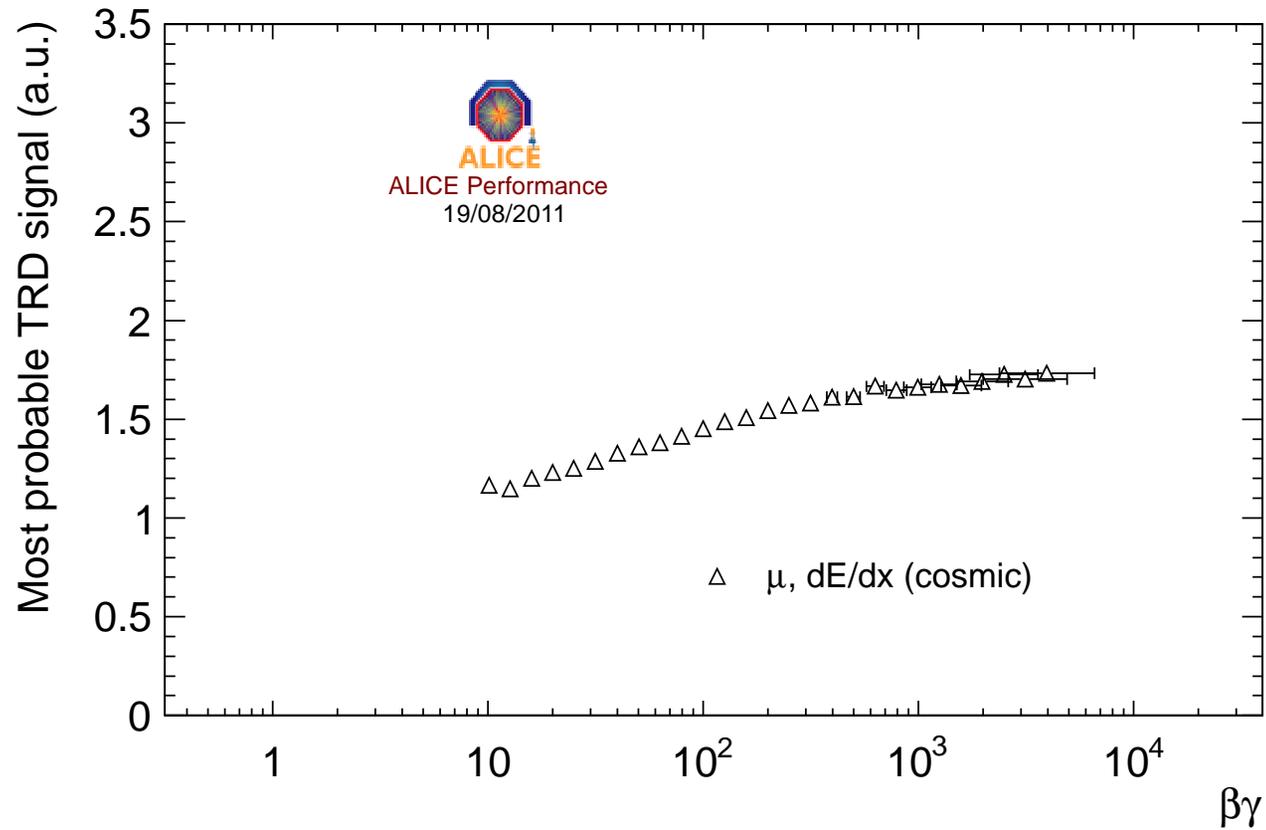


$\sigma\left(\frac{1}{p_t}\right)$  with TPC combined track fit:

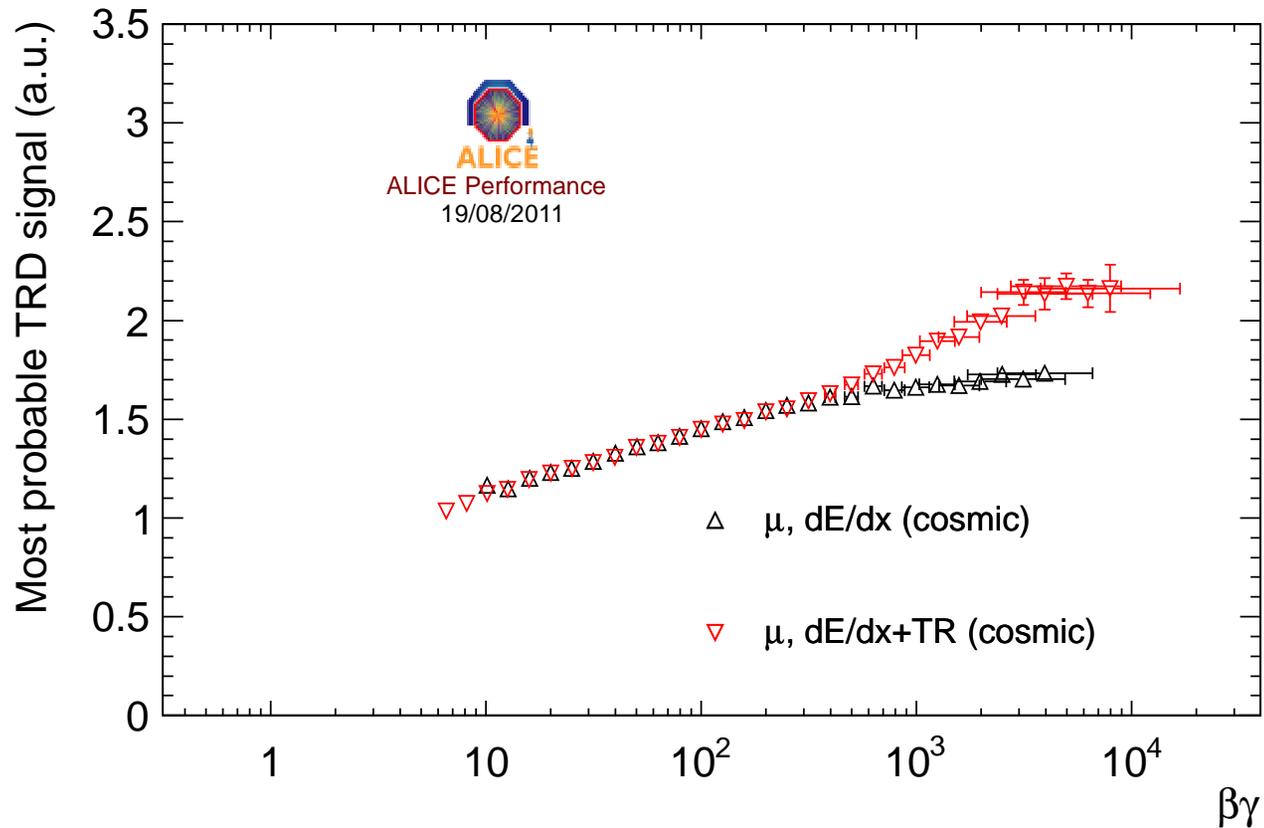
$$8.1 \times 10^{-4} \text{ c/GeV@100 GeV/c,}$$

compared to  $8.4 \times 10^{-3} \text{ c/GeV@100 GeV/c}$  with the standard.

# TRD Signals from Cosmic Rays – Pure dE/dx

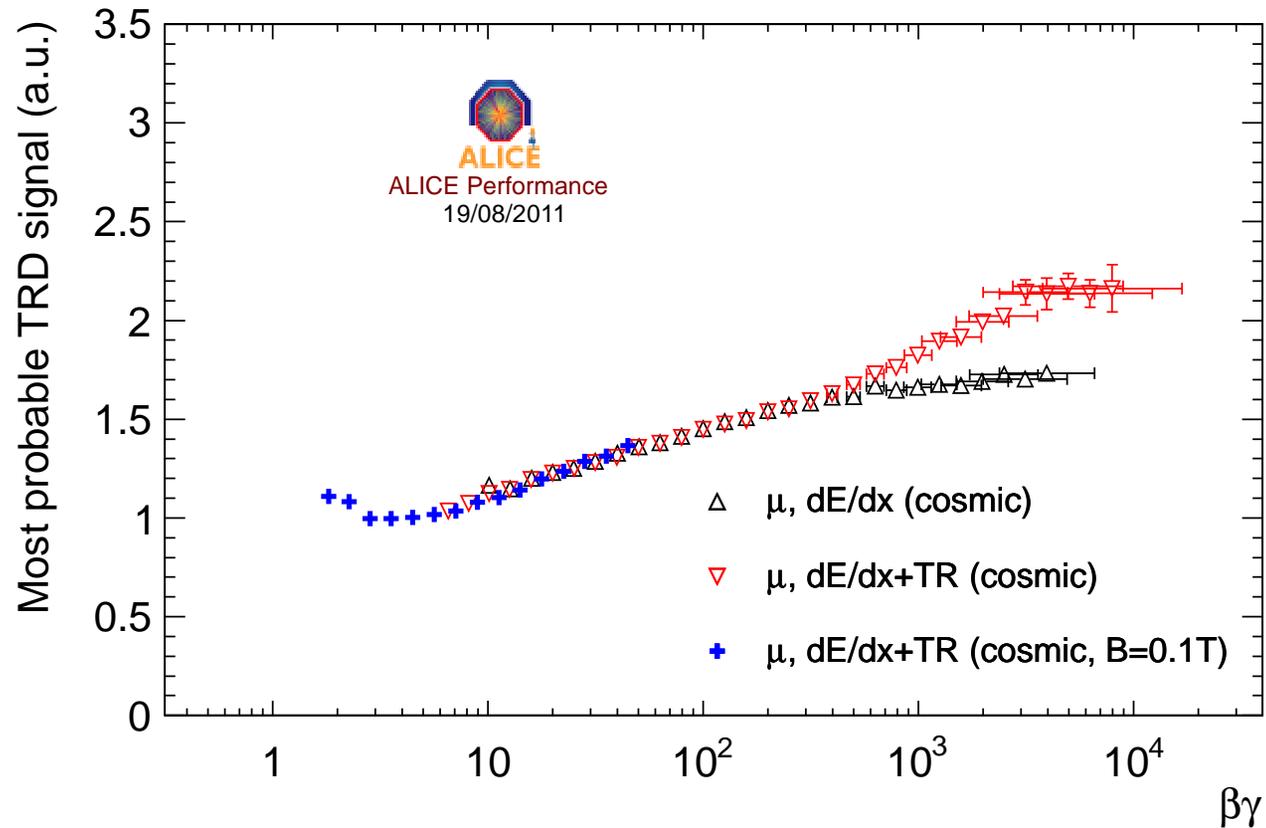


# TRD Signals from Cosmic Rays – $dE/dx+TR$

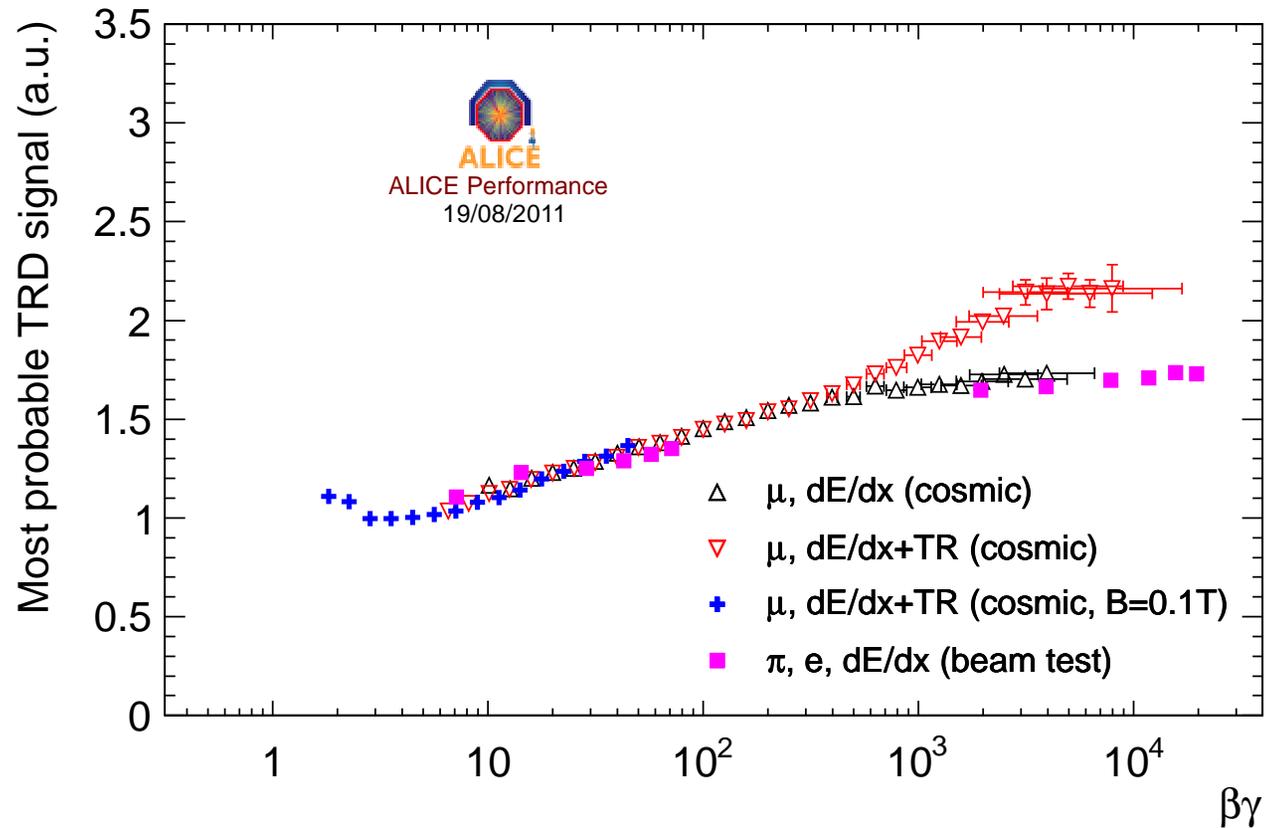


- TR onset @  $\beta\gamma \simeq 500$
- TR from 100 GeV muons observed

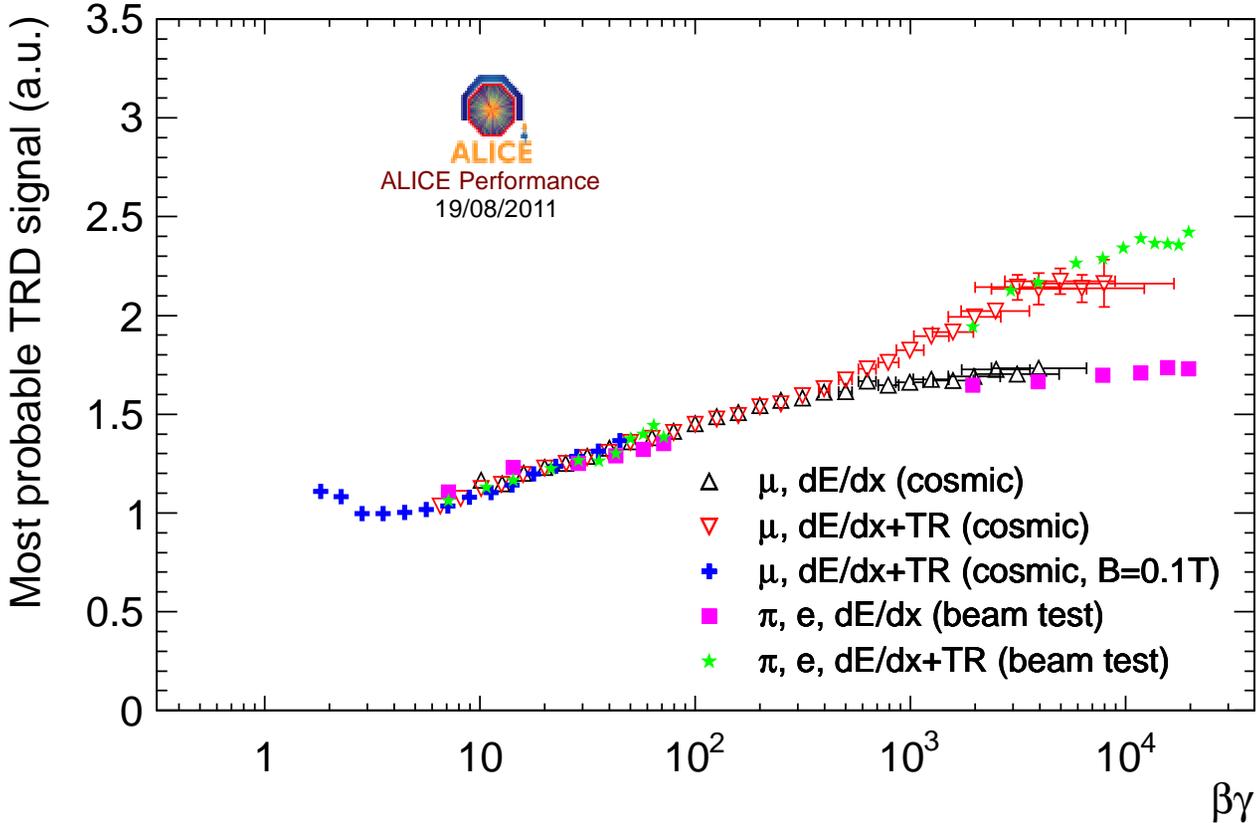
# TRD Signals from Cosmic Rays – $dE/dx+TR$ @ $B=0.1$ T



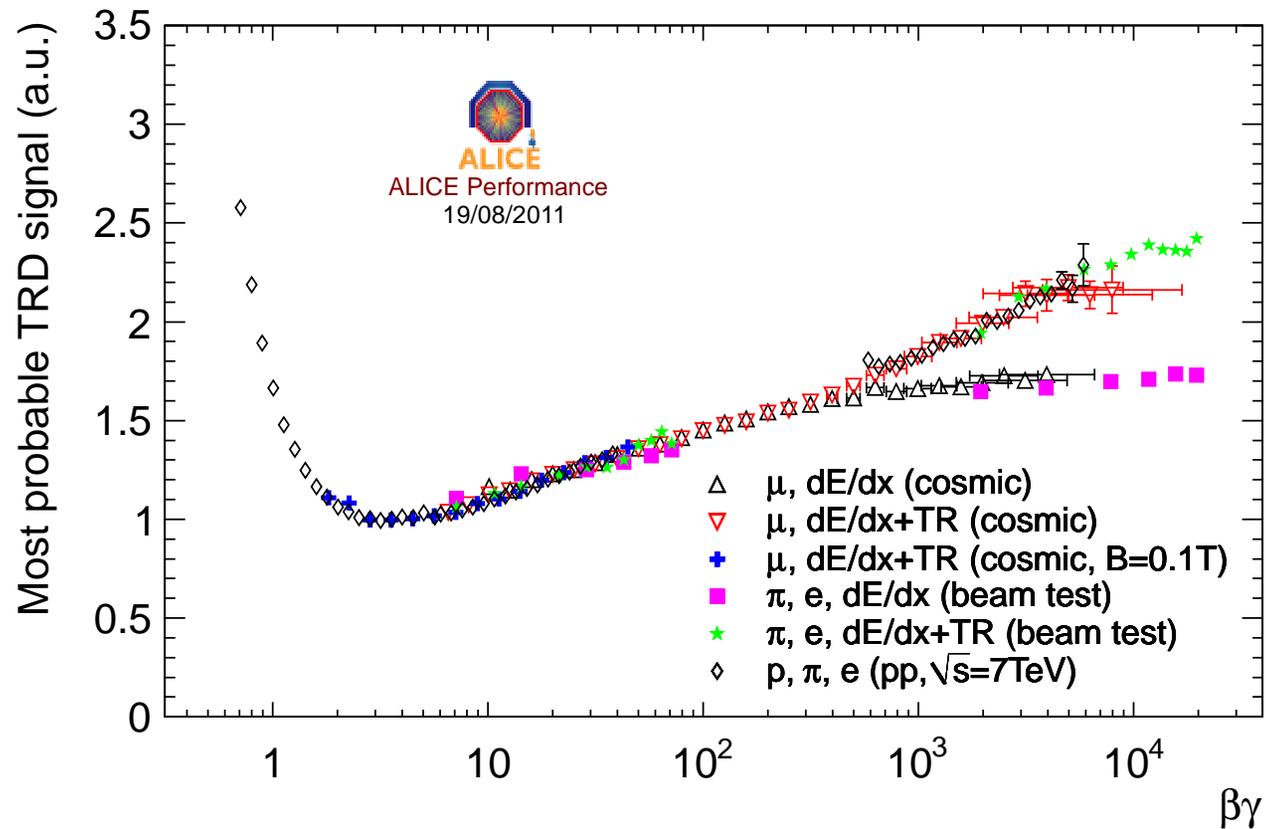
# TRD Signals from Testbeam – Pure dE/dx



# TRD Signals from Testbeam – dE/dx+TR

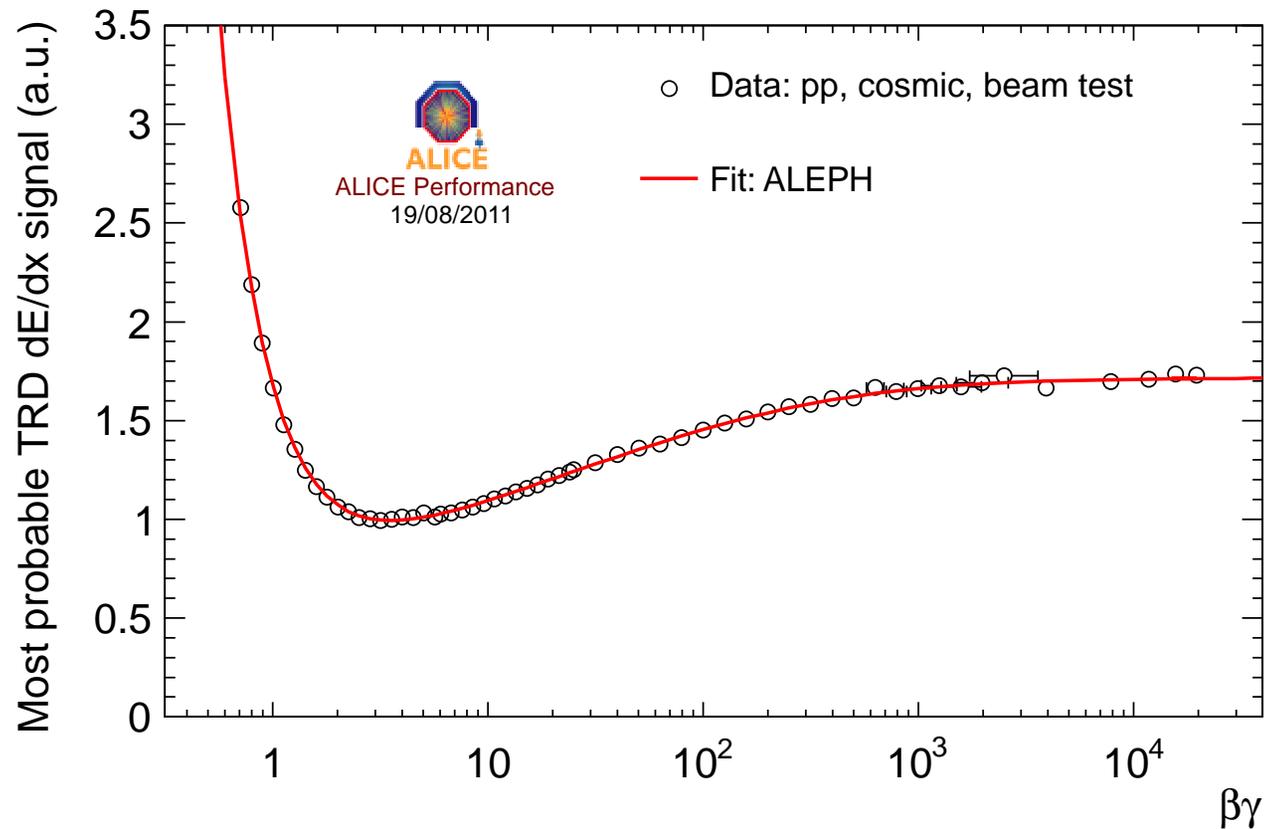


# TRD Signals from Proton-Proton Collisions



$\beta\gamma$  ranges over 4 orders of magnitude, from below 1 to above  $10^4$ .

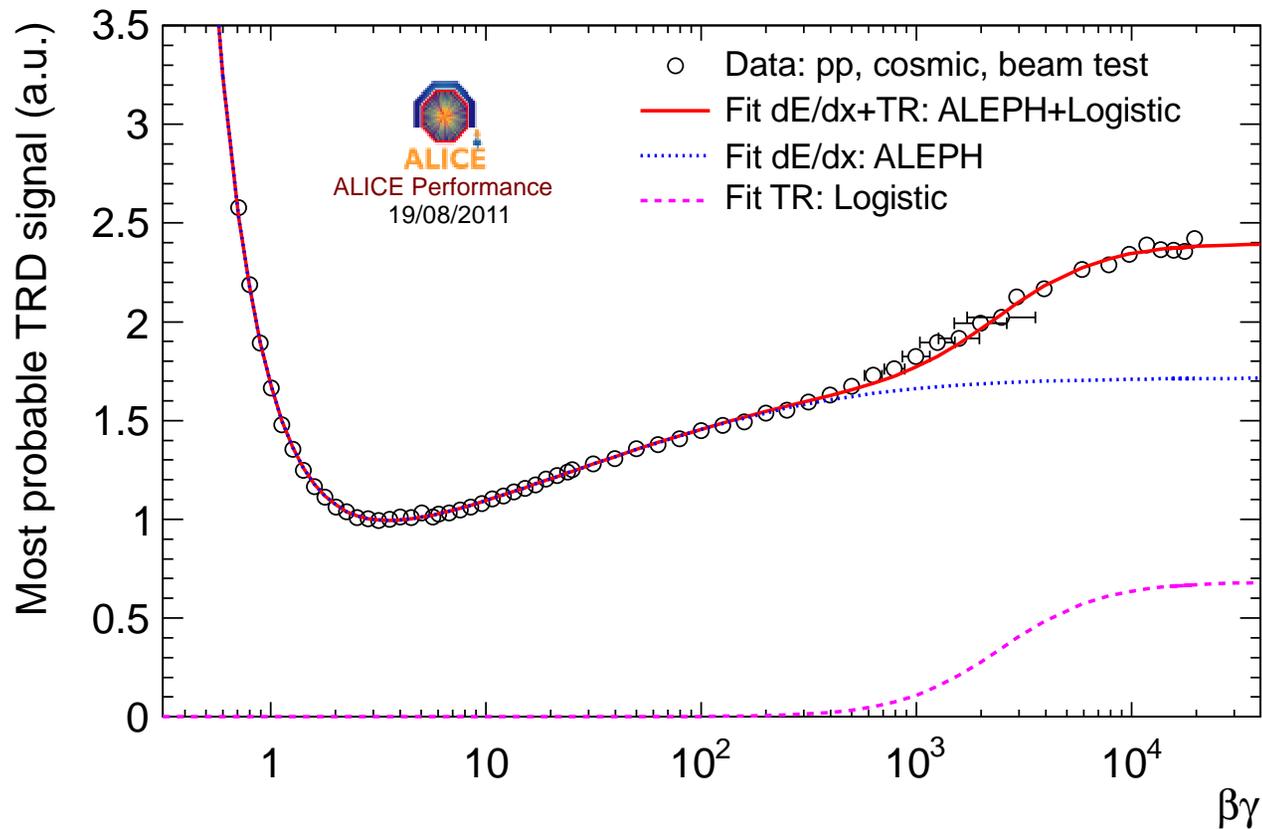
# Fit of $\beta\gamma$ -dependence



Compilation of TRD  $dE/dx$  data from proton-proton collisions, cosmic rays and testbeam. Fit with ALEPH parametrization:

$$0.19 \times \frac{4.4 - \beta^{2.26} - \ln \left[ 0.004 + \frac{1}{(\beta\gamma)^{0.95}} \right]}{\beta^{2.26}}.$$

# Fit of $\beta\gamma$ -dependence



Fit with a **logistic function in addition to ALEPH parametrization** (fixed according to previous fit to dE/dx data). Fitted logistic function:

$$\frac{0.683}{1 + \exp^{-1.85 \times (\ln \gamma - 7.80)}}$$

# Application in Particle Identification

Bayes' theorem:

$$f(e|\Delta) = \frac{f(\Delta|e)f(e)}{\sum_{i=p,K,\pi,e,\dots} f(\Delta|i)f(i)}$$

- Energy loss  $\Delta$
- Energy loss distributions:  $f(\Delta|i)$  ( $i = p, K, \pi, e, \dots$ )
- Prior probability density:  $f(i)$  ( $i = p, K, \pi, e, \dots$ )
- Probability that a track with  $\Delta$  is an electron:  $f(e|\Delta)$

For particle identification with TRD it is important to have a precise measurement of the energy loss distributions.

The TRD signal measurements discussed before cover a  $\beta\gamma$  range over 4 orders of magnitude, and thus provide important information for the reference distribution  $f(\Delta|i)$ .

# Summary

1. ALICE TRD signals from testbeam, proton-proton collisions and cosmic ray have been summarized. Results are consistent.
2. Observations:
  - The measurements cover a  $\beta\gamma$  range over 4 orders of magnitude, from below 1 to above  $10^4$ . The onset of TR is observed.
  - TR from 100 GeV cosmic muons has been measured.
3. Useful techniques:
  - Modified Landau distribution with exponential weighting was introduced to describe energy loss per unit length in TRD. Distributions of pure  $dE/dx$  and  $dE/dx$  with TR are both well described.
  - The logistic function was found to describe well the TR production as a function of  $\ln \gamma$ .
  - It was realized that the pure  $dE/dx$  signal can be measured in final TRD with particles propagating in the drift-chamber-radiator direction.
4. Special efforts:
  - Special TPC track fit algorithm was developed for high momentum cosmic rays.
  - Special cosmic data taking with 0.1 T B-field for detection of MIP was carried out, being the first ALICE 0.1 T running.

# References

- [ALI03] A. Andronic *et al.* [ ALICE Collaboration ], Nucl. Instrum. Meth. **A519** (2004) 508-517. [physics/0310122].
- [ALI05] A. Andronic *et al.* [ ALICE Collaboration ], Nucl. Instrum. Meth. **A558** (2006) 516-525. [physics/0511229].
- [Ems10] D. Emschermann, "Construction and Performance of the ALICE Transition Radiation Detector", PhD Thesis, U. Heidelberg, 2010.

# Backup

