Particle Identification in the Inner Tracking System of ALICE

Emanuele Biolcati
for the ALICE Collaboration

Università e INFN di Torino

V Convegno Nazionale sulla Fisica di ALICE
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1 Introduction
   - PID in ITS

2 SDD calibration
   - SDD effect correction

3 PID2 algorithm
   - The Bayesian approach
   - PID results

4 Conclusion
Reconstruction of primary vertex with resolution below 100 µm

Prolong TPC tracks to the primary vertex. ITS crucial for $p_t$ and impact parameter resolution

Track and identify particles missed by the TPC ($p_t$ cutoff, decays, acceptance)

Detection of secondary vertices from hyperons, $K_s^0$ and heavy flavor decays
Features of ITS as standalone tracker
(Thanks to Francesco Prino and Andrea Dainese)

Resolution

Comparable resolution for ITS standalone and ITS+TPC tracks

Efficiency

ITS standalone

Importance of extending seeding to outer layers

Reconstructed / trackable

Physical Tracking Efficiency (-0.9 < η < 0.9)

Reconstructed / Generated

ITS standalone allows to recover particles not reconstructed in TPC
The PID in the ITS

Simulation of $p$-$p$ events

Possible to distinguish $p$, $K$ and $\pi$ only

PID in ITS will be important for all tracks missed by TPC ($\approx 10\%$)

PID in ITS is crucial when ITS is used as a standalone tracker
PID algorithm in ITS

AliITSpidESD1.h

- \( dE/dx \) obtained as truncated mean of the cluster charge read by the 4 ITS outer layers (tails cut \( \rightarrow \) distributions fitted by a Gaussian)
- conditional probabilities calculated from a sigma cut of \( dE/dx \) value obtained with the Bethe-Bloch formula for a given particle with a given momentum

AliITSpidESD2.h

- based\(^1\) on the convoluted Landau-Gaussian fits to the \( dE/dx \)
- signal from each SDD and SSD layer individually treated

\(^1\) E. Bruna, *Response functions for Particle Identification in the Inner Tracking System*, ALICE Internal Note (October 2006)
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Conclusion
Electron cloud, generated in the Si, spreads during the drift
Signal tails could be cut by the zero-suppression algorithm
For each SDD layer, charge distributions plotted in drift time bins and fitted by Landau+Gaussian convolution
Fit parameter plotted versus drift time (next slide)
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**PID results**

**Conclusion**

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**SDD: drift time dependence, results for layer 3**

**p-p events simulation**

Dependence on drift time (data are zero-suppressed)

**Cosmic data in Turin, single module**

No dependence on drift time for non zero-suppressed data
SDD: correction for zero suppression

Correction in the code:

```cpp
q /= rsdd->GetADC2keV();
q += (driftTime * rsdd->GetChargevsTime());
```

![Graph showing simulation and data with Landau MPV vs Drift Time](image)
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**PID2 status**

**Done:**
- $Pb - Pb$ events (by Elena Bruna) but...
  - response functions $R(S)$ obtained with old ADC charge scale and old detector description
  - possible differences with respect to $p-p$ events
  - correction for detector systematics (i.e. SDD drift time)

**On going:**
- $R(S)$ with new keV charge scale
- $p-p$ events

**To do:**
- cosmics: comparison between simulation and reconstruction to validate the $R(S)$
- $Pb - Pb$ events
Evaluation of the response functions:

- Event generation (PYTHIA or HIJING)
- Tracking in ITS (tracks with 4 clusters in SDD and SSD)
- For each reconstructed track, all the 4 charge signals coming from the 4 different layers (SDD+SSD) retrieved
- $dE/dx$ histograms in momentum slices 0.032 GeV/c wide
- For each momentum bin, $dE/dx$ distribution for $p$, $K$, $\pi$ ($i.e.$ $R(S)$) fitted by Landau-Gaussian convolution
- Four fit parameters:
  - Width Landau (WL)
  - Most Probable Value (MP)
  - Total Area (neglected)
  - Width Gaussian (WG)
- $R(S)$ normalized to its total area
PID2 algorithm II

- Fit parameters plotted versus momentum bins and fitted by ad hoc functions: \( f_{WL}, f_{MP}, f_{WG} \):

\[
\begin{align*}
\text{Pions} & \\
& \begin{cases}
  f_{WL} = A + \frac{B}{p^2} + \frac{C}{p^2} \log p^2 \\
  f_{MP} = A + \frac{B}{p^2} + \frac{C}{p^2} \log p^2 \\
  f_{WG} = A + \frac{B}{p^2} + \frac{C}{p^2} \log p^2
\end{cases}
\end{align*}
\]

\[
\begin{align*}
\text{Kaons, Protons} & \\
& \begin{cases}
  f_{WL} = A + \frac{B}{p^2} \\
  f_{MP} = A + \frac{B}{p^2} + \frac{C}{p^2} \log p^2 \\
  f_{WG} = A + \frac{B}{p^2} + \frac{C}{p^2} \log p^2
\end{cases}
\end{align*}
\]

- Bayesian approach: probability for a track of momentum \( p \), with measured \( dE/dx \), to be of type \( i \):

\[
P(i|S) = \frac{R(S|i)P(i)}{\sum_{t=p,K,\pi} R(S|t)P(t)}
\]

where \( S=dE/dx \), \( P(i) \) are the priors

- Recursive method:
  - first step: \( P(i) = \frac{1}{3} \) for \( \pi, K, p \)
  - next steps: \( P'(i) = \frac{N_i}{N_{tot}} \), where \( N_i \) particles with \( P(i|S) > \text{threshold} \)
Binning in momentum

- For each particle specie, for each layer (SDD and SSD), binning in momentum is performed
- 50 bins 32 MeV/c wide, from 0 to 1.6 GeV
- Fit parameters are stored to be plotted versus momentum

Example

Layer 4
Particle $\pi$
$P \in [320 \, \text{MeV}, 352 \, \text{MeV}]$

Estimation of resolution
$\sqrt{WL^2 + WG^2} \simeq 10 \, \text{keV}$
Fit parameters: p-p events, layer 3 SDD, pions

**WL_layer2**

$\chi^2 / \text{ndf} = 18.41 / 46$

Prob = 0.9999

$p_0 = 0.3812 \pm 0.064$

$p_1 = 0.07207 \pm 0.01632$

$p_2 = 8.487 \pm 0.1405$

**MPV_layer2**

$\chi^2 / \text{ndf} = 51.74 / 45$

Prob = 0.2274

$p_0 = 3.429 \pm 0.2824$

$p_1 = 0.502 \pm 0.06261$

$p_2 = 6.235 \pm 0.435$

$p_3 = 90.18 \pm 0.3921$

**WG_layer2**

$\chi^2 / \text{ndf} = 80.38 / 46$

Prob = 0.001278

$p_0 = -0.7642 \pm 0.1337$

$p_1 = -0.192 \pm 0.03411$

$p_2 = 14.77 \pm 0.2937$

**Simulation**

p-p events

layer: 3

particle code: 211
Fit parameters: p-p events, layer 4 SDD, protons

**WL_layer3**
- $\chi^2 / \text{ndf}$: 213.6 / 31
- Prob: 3.769e-29
- $p_0$: $10.99 \pm 3.459$
- $p_1$: $4.458 \pm 2.784$
- $p_2$: $6.118 \pm 3.011$

**MPV_layer3**
- $\chi^2 / \text{ndf}$: 173.6 / 30
- Prob: 3.821e-22
- $p_0$: $170.6 \pm 31.27$
- $p_1$: $41.23 \pm 14.66$
- $p_2$: $44.22 \pm 15.3$
- $p_3$: $-13.03 \pm 31.39$

**WG_layer3**
- $\chi^2 / \text{ndf}$: 1102 / 31
- Prob: 0
- $p_0$: $14.75 \pm 7.857$
- $p_1$: $9.992 \pm 6.324$
- $p_2$: $1.645 \pm 6.84$

**Simulation**
- p-p events
- layer: 4
- particle code: 2212
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Fit parameters: p-p events, layer 5 SSD, kaons

Simulation
p-p events
layer: 5
particle code: 321
Contamination and efficiency: definition

- Test and improve of pidESD2:
  - check the $R(S)$ calculated by the recursive method
  - fine tuning of the ad hoc fit functions

- Using contamination/efficiency:
  \[
  \text{efficiency} = \frac{N_{\text{good}}}{N_{\text{true}}}
  \]
  \[
  \text{contamination} = \frac{N_{\text{fake}}}{N_{\text{identified}}}
  \]

- Using fractions (for example for $\pi$):
  \[
  N(\pi|\pi) = \frac{\text{true } \pi \text{ identified as } \pi}{\text{true } \pi}
  \]
  \[
  N(\pi|K) = \frac{\text{true } \pi \text{ identified as } K}{\text{true } \pi}
  \]
  \[
  N(\pi|p) = \frac{\text{true } \pi \text{ identified as } p}{\text{true } \pi}
  \]
Contamination and efficiency: kaons

Kaons (ITS)

kaons
300 k entries
p-p events
ITS standalone
Contamination and efficiency: pions

300 k entries
$p-p$ events
ITS standalone
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Conclusions

Landau+Gaussian PID in ITS

Work in progress to tune the response functions taking into account:
- new keV charge scale
- correction for detector systematics (i.e. SDD drift time)
- $p$-$p$ events (simulation)

Results and future...

- Contamination and efficiency values good for low momentum particles
- To do: cross check using cosmic data
- Algorithm will be ready for first $p$-$p$ collisions (data)
- It will be possible to perform $dN/dp_t$ and $dN/dy$ distributions using ITS in standalone mode → particles at lower $p_t$ reach with respect to TPC based analysis
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That’s all, thanks.
Part I

Backup slides
Zero-suppression effect simulation (I)

Signal read by anodes

Drift Coordinate

Anodic coordinate
Zero-suppression effect simulation (II)

**Zero suppression effect**

![Graph showing the relationship between integral of charge and drift path.]

- $\chi^2 / \text{ndf}$: 2.743e-06 / 16
- $p_0$: $3.287 \pm 0.0001963$
- $p_1$: $-0.001492 \pm 1.045e-05$