Triggering with the ALICE TRD

Jochen Klein
for the ALICE collaboration

Physikalisches Institut
University of Heidelberg

TRDs for the Third Millenium
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Outline

- triggering in ALICE
- concept of the TRD triggers
- on-line reconstruction
- on-line electron identification
- triggers with the TRD
ALICE trigger detectors

- V0
- SPD
- EMCAL
- PHOS
- TRD
  - full coverage of central barrel: $|\eta| < 0.9, \varphi \in [0, 2\pi]$
  - $e/\pi$-separation by transition radiation
  - short drift time $\approx 2\mu s$
  - track reconstruction in Front-End Electronics
- muon spectrometer (forward)
### ALICE trigger scheme

- Constraints on trigger rates (pp):

| level | time after int. | limited by | limit     |
|-------|-----------------|------------|-----------|
| L0    | $\sim 800$ ns   | dead time  | $\sim 100$ kHz |
| L1    | $\sim 7$ $\mu$s | read-out bandwidth | $\sim 2.5$ kHz |
| L2    | $\sim 100$ $\mu$s | input to High-Level Trigger | $\sim 1.5$ kHz |
| HLT   |                 | 1 GB/s to tape |           |

- so far mostly min. bias data taking

- rare triggers (L0) for the central barrel started this summer
  - EMCAL: jets
  - PHOS: photons and jets
  - SPD double-gap: diffractive events

- level-1 triggers from EMCAL and TRD
Concept

10/18 TRD supermodules currently installed

- track segments in TRD layers (tracklets)
- match tracklets $\rightarrow$ tracks
- straight line fit $\rightarrow$ $p_\perp$
- average electron likelihood $\rightarrow$ PID
- track-based triggers

TRD trigger based on partial readout (tracklets)
$\Rightarrow$ high Level-0 rate needed
Track-based triggers

- single high-$p_{\perp}$ particle
e.g. used for cosmics

- high-$p_{\perp}$ jet
  requiring minimum number of tracks above $p_{\perp}$ threshold
  comprises single high-$p_{\perp}$ as degenerate case

- single high-$p_{\perp}$ electron
  combining tracklet PID to global PID

- di-electron
  requiring two tracks of opposite charge
  ultimately calculating invariant mass, e.g. for $J/\Psi$, $\Upsilon$
Readout tree

- hierarchical readout
- no back-pressure, low latency
On-line reconstruction

- chamber-wise tracking (ASICs)
  - digitization
  - digital filtering
  - cluster finding
  - straight line fit + corrections + $p_\perp$-cut

- stack-wise tracking in Global Tracking Unit (FPGA based)

- calculate L1 trigger based on $p_\perp$ + PID of individual tracks

\[ y, d_y \text{ from fit} \]
\[ z \text{ from pad row} \]
\[ \text{PID from } Q_0, Q_1 \]
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Multi-Chip Module (PASA + TRAP): amplification + digital processing connected to 18+3 pads

timebin ↔ radial position
ADC channel ↔ transverse position
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Multi-Chip Module (PASA + TRAP): amplification + digital processing connected to 18+3 pads

Data of MCM 15 on ROB 1 in detector 94

```
| Timebin | ADC Channel |
|---------|-------------|
| 0       | 5           |
| 5       | 10          |
| 10      | 15          |
| 15      | 20          |
| 20      | 25          |
```

timebin ↔ radial position
ADC channel ↔ transverse position

Jochen Klein (Univ. of Heidelberg)
On-line reconstruction

Digital filtering

ADC data

Non-Linearity Filter

Pedestal Filter

Gain Correction Filter

Tail Cancellation Filter

Crosstalk Filter

Event Buffer

Pedestal filter
common baseline for all channels

Gain correction

\[ O(t) = \gamma_n \cdot I(t) + \rho_n \]

values taken from Krypton calibration
(s. talk by Johannes Stiller)

tail cancellation

\[ S(t) = 1_{(t \geq 0)} \cdot (\alpha_{long} \lambda_{long}^t + (1 - \alpha_{long}) \lambda_{short}^t) \]
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Data of MCM 15 on ROB 1 in detector 94

- timebin $\leftrightarrow$ radial position
- ADC channel $\leftrightarrow$ transverse position
On-line reconstruction

Cluster finding

- cluster detected charge sum of three adjacent channels exceeds threshold
- position calculated as:

\[ y_{\text{COG}} = \frac{1}{2} \frac{R - L}{C} \]

(values are baseline-subtracted)
- correction from PRF:

\[ \Delta y(y_{\text{COG}}) = y - y_{\text{COG}} \]
- LUT calculated off-line
On-line reconstruction

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data of MCM 15 on ROB 1 in detector 94

timebin $\leftrightarrow$ radial position
ADC channel $\leftrightarrow$ transverse position
On-line reconstruction
Tracklet composition

- straight line fit calculated from accumulated charge sums in two adjacent channels

- Lorentz correction
  \[ \Psi_L = \tan(\omega \tau) \]

- tilted pad correction
  \[ \Delta y = d_{\text{drift}} \cdot \tan(\alpha_{\text{tilt}}) \cdot \frac{z}{x} \]

- ship information on transverse position, deflection, pad row and PID
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Exact simulation

- all calculations done on digitized data which are read out
- allows for detailed re-simulation of the full trigger chain
- simulation of TRAP and GTU
Tracklet performance – Monte-Carlo

- use simulation to understand influence of different parameters
- optimize efficiency multiple finding of tracklets expected from the algorithm
- achieve good position resolution of $\sim 200\mu m$
- achieve good deflection resolution of $\sim 400\mu m$ (without tail cancellation)
Tracklet performance – data

- fit through tracklets assigned to a track
- plot residuals in position and deflection
- independent of any other data on-line monitoring
- check for correct drift velocity

pp @ 7 TeV

Jochen Klein (Univ. of Heidelberg)  Triggering with the ALICE TRD  Bari, Sep 2011
Tracking performance

- geometrically match on-line track to off-line track
- compare $p_\perp$
- tracking performs well up to high-$p_\perp$
- deviation from diagonal for very high $p_\perp$ expected from algorithm
- resolution about 15\% to be further improved by FEE tuning
Trigger performance

- Efficiency for "good" tracks:
  \[ \frac{N_{\text{matched}}}{N_{\text{findable}}} \]

- \(N_{\text{findable}}\): off-line tracks with at least 4 TRD tracklets

- \(N_{\text{matched}}\): track which is geometrically matched to a findable one

- Compare off-line \(p_\perp\) when applying cut on on-line \(p_\perp\)
Processing optimized for low latency tracking starts upon arrival of the first data.

Total tracking time depends on multiplicity.
$e^\pm$ identification – strategy

- Summing charge in two configurable time windows
- Enter lookup table with $Q_0$ (and $Q_1$)
- At the moment total charge is used
- Assign electron likelihood to tracklet

 Lookup table is freely configurable
 ⇒ calculate off-line
e^± identification – reference data

- clean input sample from
  \[ \gamma \rightarrow e^+ e^- \]
  \[ K^0 \rightarrow \pi^+ \pi^- \]

- fit charge deposition
  \[(\text{Exp} \cdot \text{Landau}) \otimes \text{Gauss}\]
  (s. talk by Xianguo Lu)

- charge dependent electron likelihood

- define cut to cover wanted fraction of the electrons
e\(^\pm\) identification – performance

- pion rejection controlled by adjusted electron efficiency
- typical values in simulation:
  - for \(\epsilon_e = 90\%\): \(\sim 40\)
- typical values in real data:
  - for \(\epsilon_e = 90\%\): \(\sim 6\)
  - for \(\epsilon_e = 80\%\): \(\sim 11\)
- differences between simulation and real data mostly understood, e.g. no on-line gain calibration yet
Cosmic trigger

- cosmic particles wanted for alignment and calibration

- first super-modules installed in horizontal position
  \[\Rightarrow\] very low rate of cosmic particles

- need for trigger on cosmic TOF as Level-0, TRD as Level-1
  very pure sample

- first version using coincident charge deposition operated since 2008
  all trigger infrastructure already commissioned

- moved to track-based trigger requiring just one track
Jet trigger – Concept

- Use on-line reconstructed tracks of charged particles
- TRD stack covers an area in $\eta$-$\varphi$ plane comparable to a typical jet cone ($R \approx 0.4$)
- Ask for $N$ tracks in one stack with $p_\perp$ above threshold
- MC simulations confirm that this trigger becomes efficient for high-$p_\perp$ jets
Jet trigger – efficiency from Monte-Carlo

- looking at PYTHIA jets produced in $p_{\perp}^{\text{hard}}$ bins
- counting no. of charged tracks above $p_{\perp}$ threshold per stack
- classification according to leading MC jet in $|\eta| < 0.5$
- compare different thresholds
Jet trigger – rejection of min. bias events

- rejection of min. bias events determined from real data
- good rejection of $\sim 10^4$ for typical threshold 3 tracks above 3 GeV/c

![Graph showing the rejection of min. bias events](image)
Jet trigger – raw spectra

- first analysis of real data
- two input samples:
  - min. bias
  - EMCAL L0
  partial overlap with TRD
- UA1 jet finder \((R = 0.4)\)
- efficiencies as expected
Challenges

- low latency trigger requires complex readout electronics
  timing very critical

- calibration must be applied already on-line

- stable gain and drift velocity needed
  feedback loop for on-line adjustment

- geometric corrections for tracklet calculation
Summary & Outlook

- TRD in use as cosmic L1 trigger since 2008
- all on-line reconstructed tracks in readout crucial for commissioning
- jet trigger in operation
- electron trigger in preparation

TRD trigger group
Bastian Bathen, Tom Dietel, Norbert Herrmann, Benjamin Hess, Stefan Kirsch, Jochen Klein, Felix Rettig, Johanna Stachel, Hannes Wessels, Uwe Westerhoff
Backup
trigger logic

\[ |p_t| \geq \text{PTA} \]

\[ |p_t| \geq \text{PTB} \]

2...6 GeV/c

3 GeV/c

0

185

pid \geq \text{PIDA}

3

255

pid \geq \text{PIDB}

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