Triggering with the ALICE TRD

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for the ALICE collaboration

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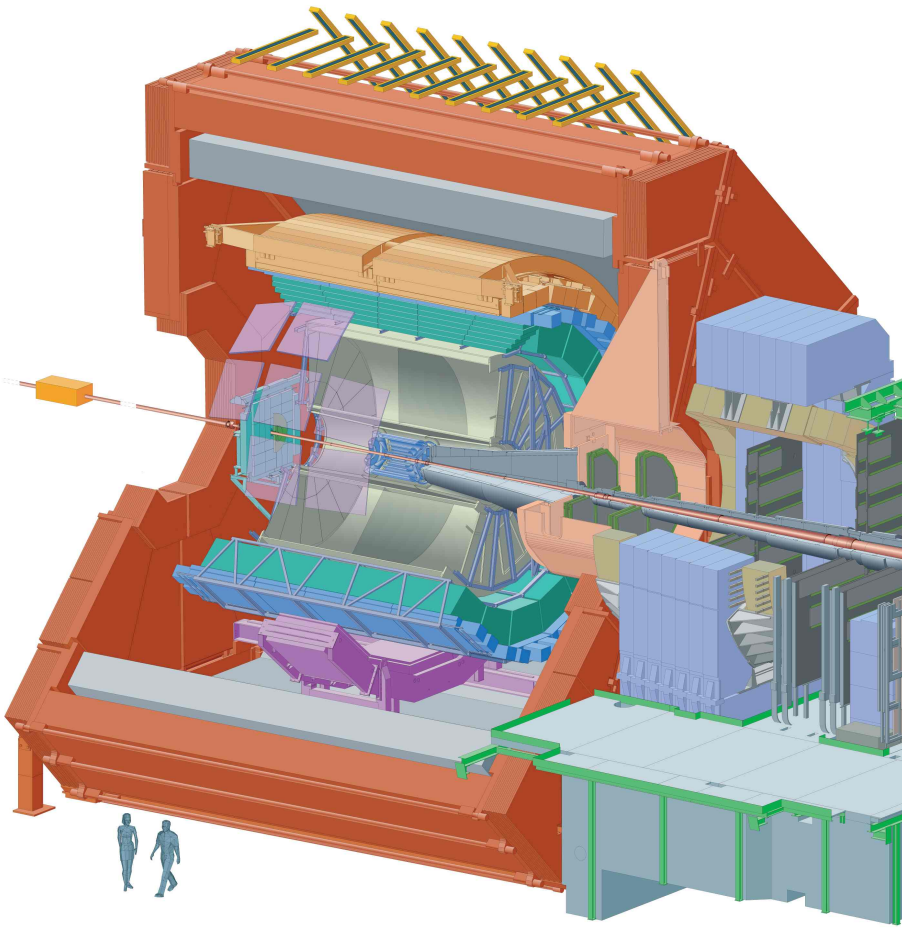
TRDs for the Third Millenium
4th Workshop on Advanced Transition Radiation Detectors
Bari, September 2011

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/π-separation by transition radiation
  - short drift time $\approx 2\mu s$
  - track reconstruction in Front-End Electronics
- muon spectrometer (forward)

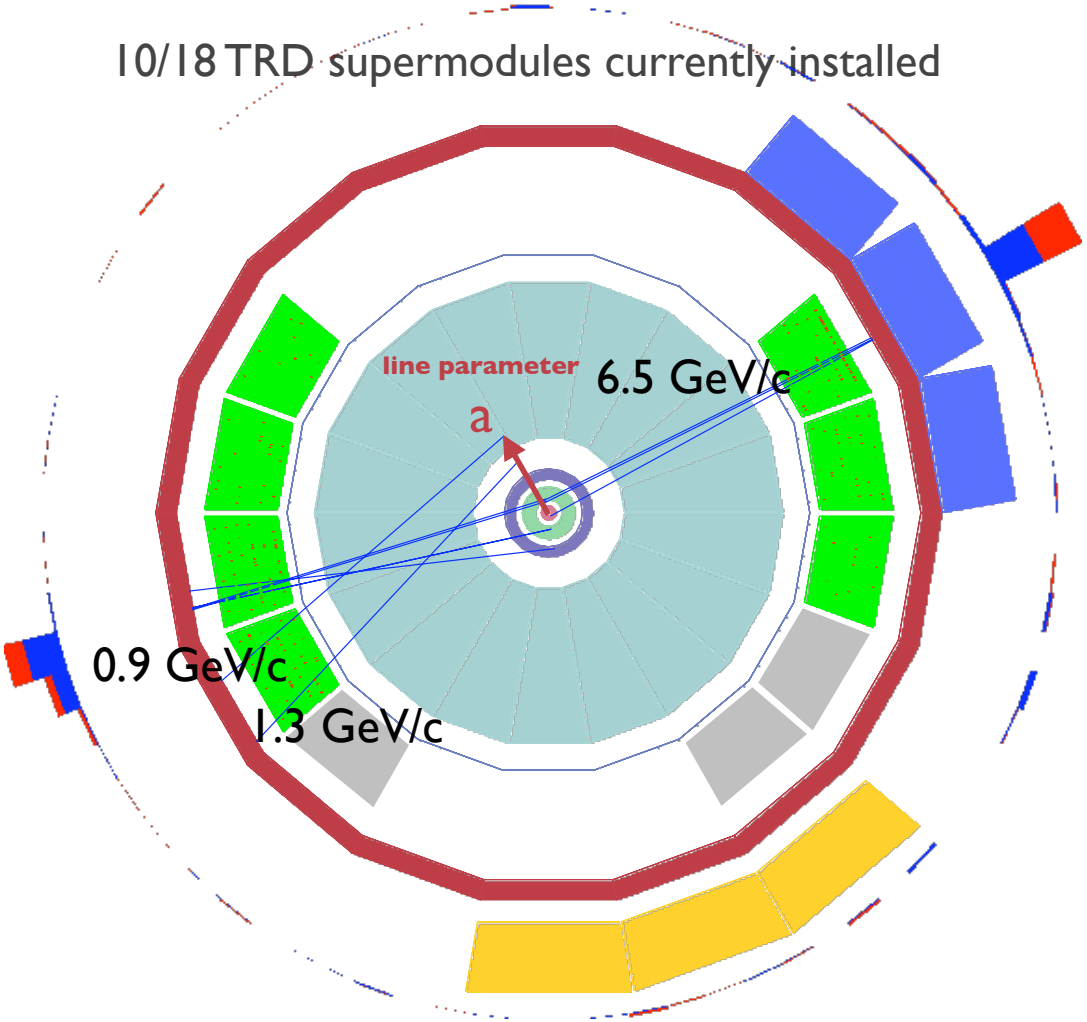
ALICE trigger scheme

- Constraints on trigger rates (pp):

level	time after int.	limited by	limit
L0	~ 800 ns	dead time	~ 100 kHz
L1	~ 7 μs	read-out bandwidth	~ 2.5 kHz
L2	~ 100 μs	input to High-Level Trigger	~ 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



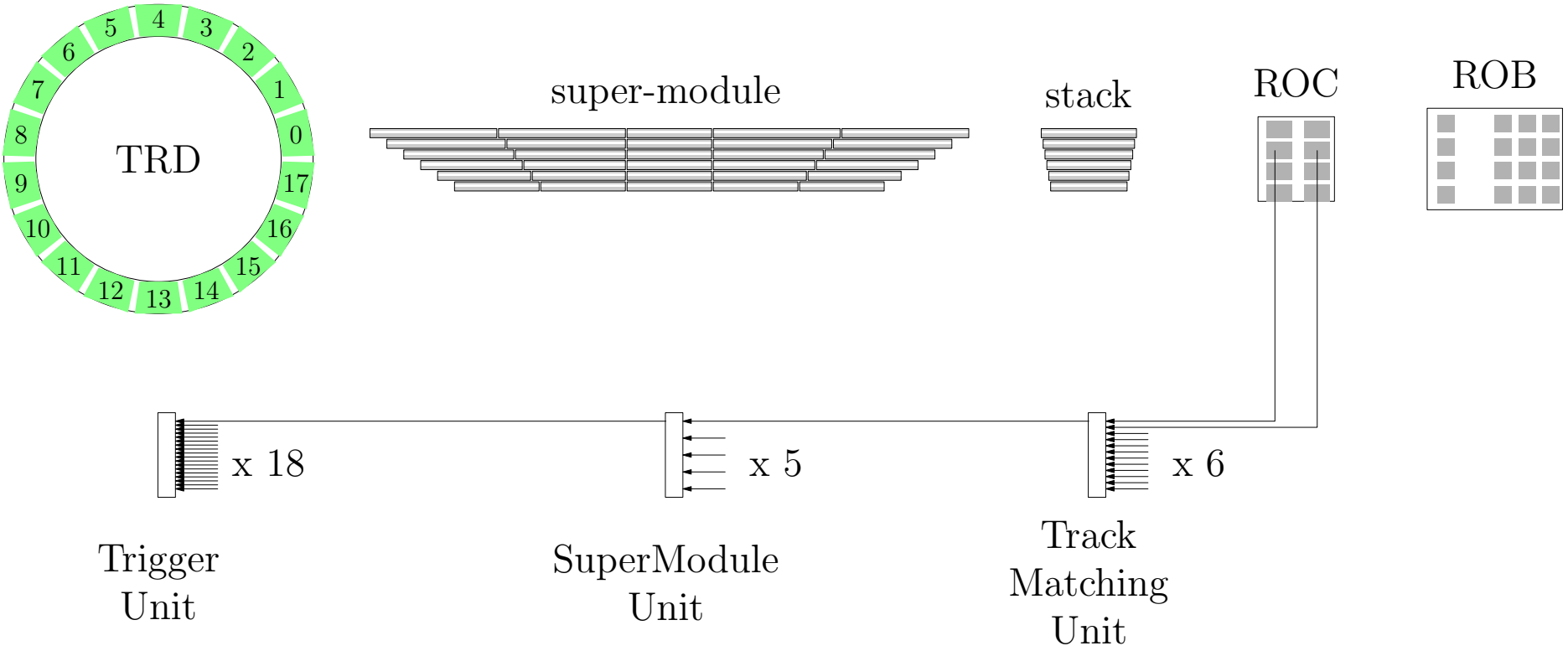
- track segments in TRD layers (tracklets)
- match tracklets → tracks
- straight line fit → $p_\perp$
- average electron likelihood → PID
- track-based triggers

TRD trigger based on partial readout (tracklets)
⇒ 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/Ψ, Υ

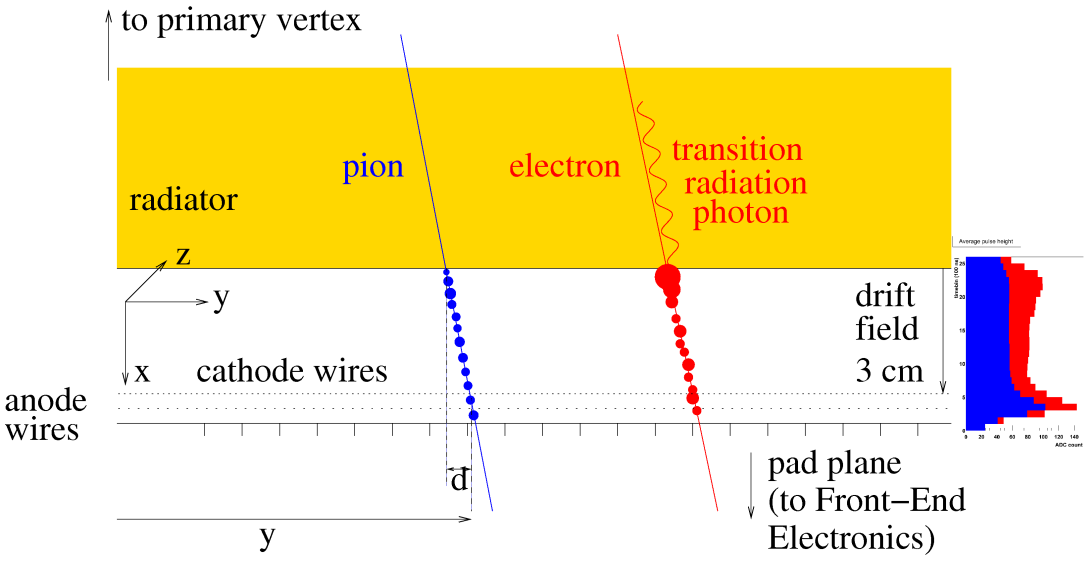
Readout tree



- 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 from fit
z from pad row
PID from Q_0, Q_1

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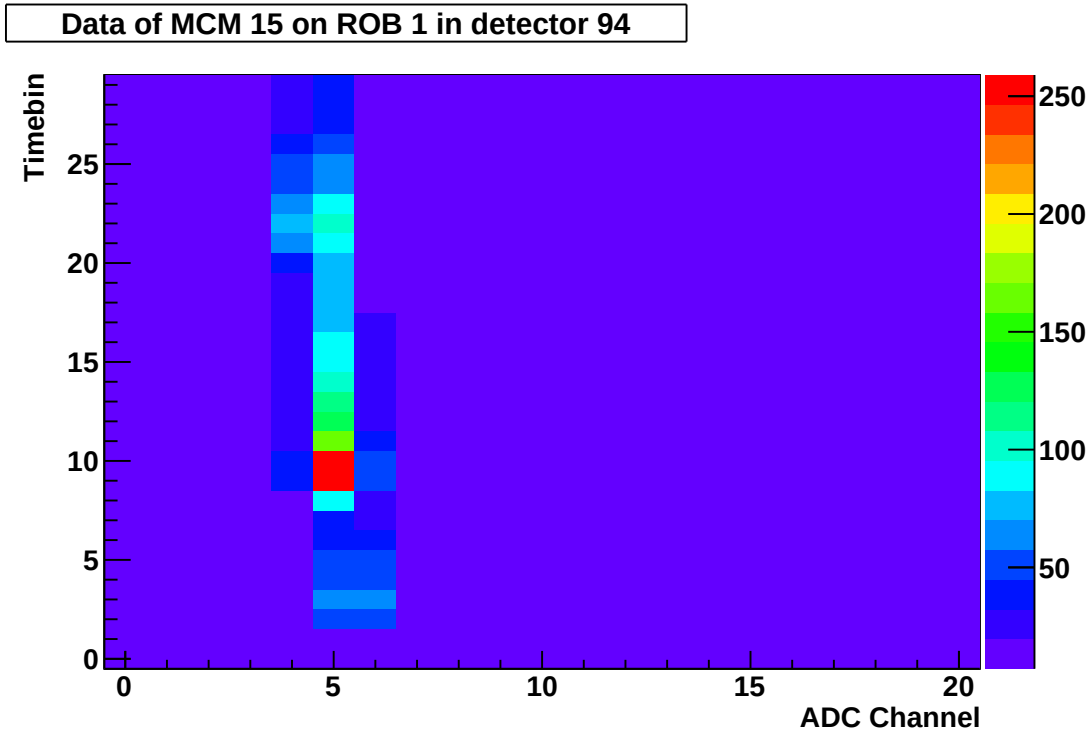
Multi-Chip Module (PASA + TRAP): amplification + digital processing connected to 18+3 pads



timebin $\leftrightarrow$ radial position
ADC channel $\leftrightarrow$ transverse position

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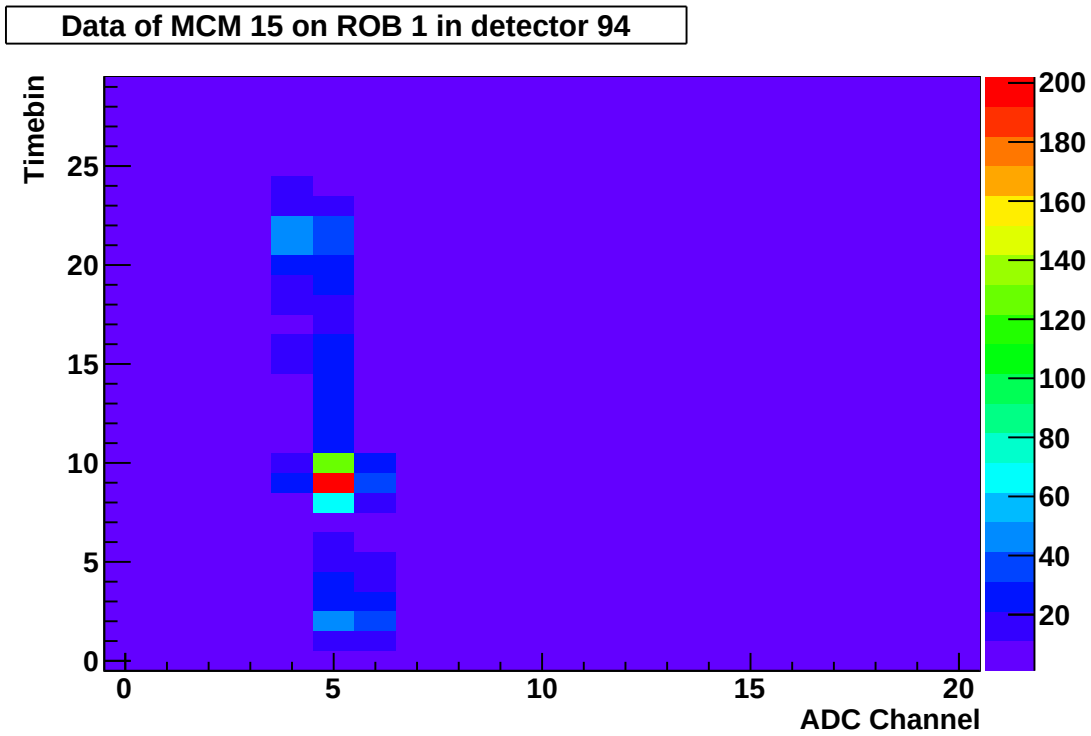

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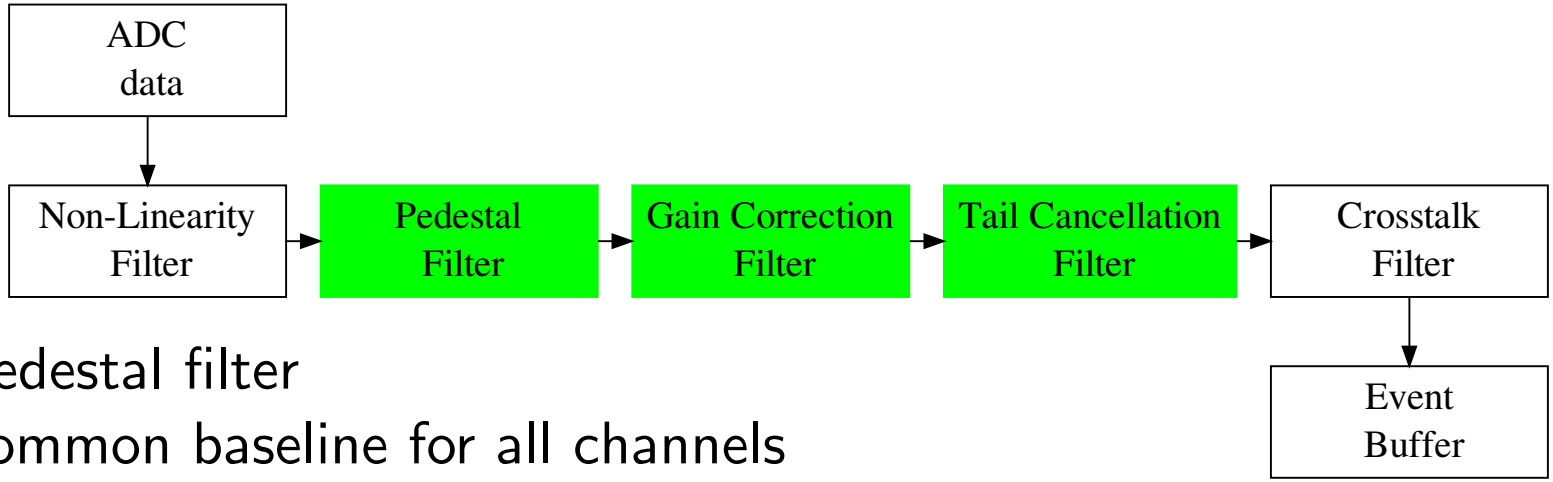
On-line reconstruction

Digital filtering



- 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

$$S(t) = 1_{(t \geq 0)} \cdot (\alpha_{\text{long}} \lambda_{\text{long}}^t + (1 - \alpha_{\text{long}}) \lambda_{\text{short}}^t)$$

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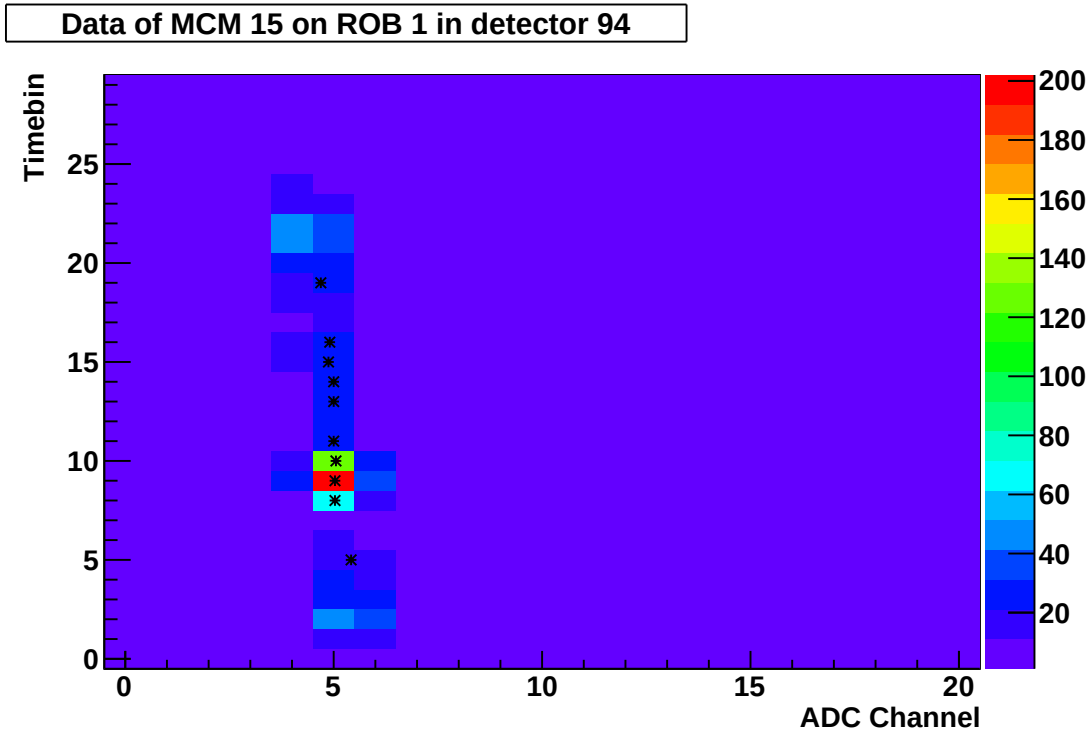


timebin $\leftrightarrow$ radial position
ADC channel $\leftrightarrow$ transverse position

On-line reconstruction

Cluster finding

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

$$y^{\mathrm{COG}} = \frac{1}{2}\frac{R-L}{C}$$

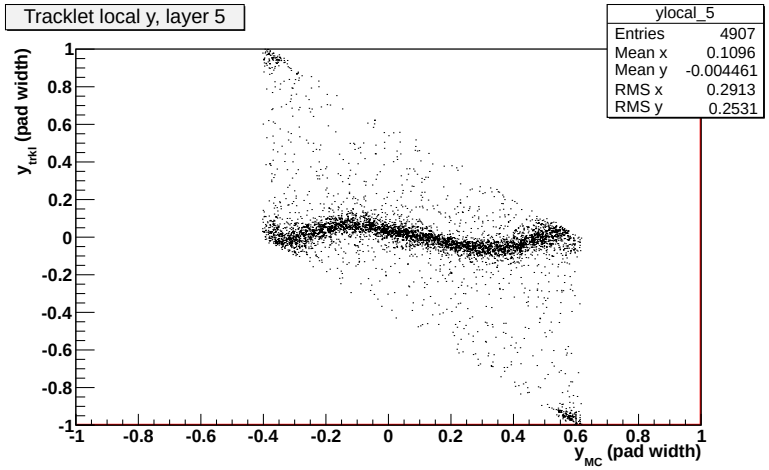
(values are baseline-subtracted)

- correction from PRF:

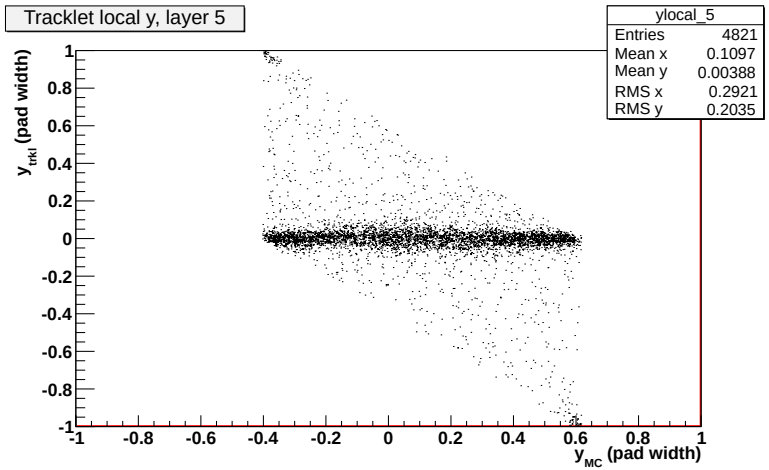
$$\Delta y(y^{\mathrm{COG}}) = y - y^{\mathrm{COG}}$$

- LUT calculated off-line

without correction



with correction



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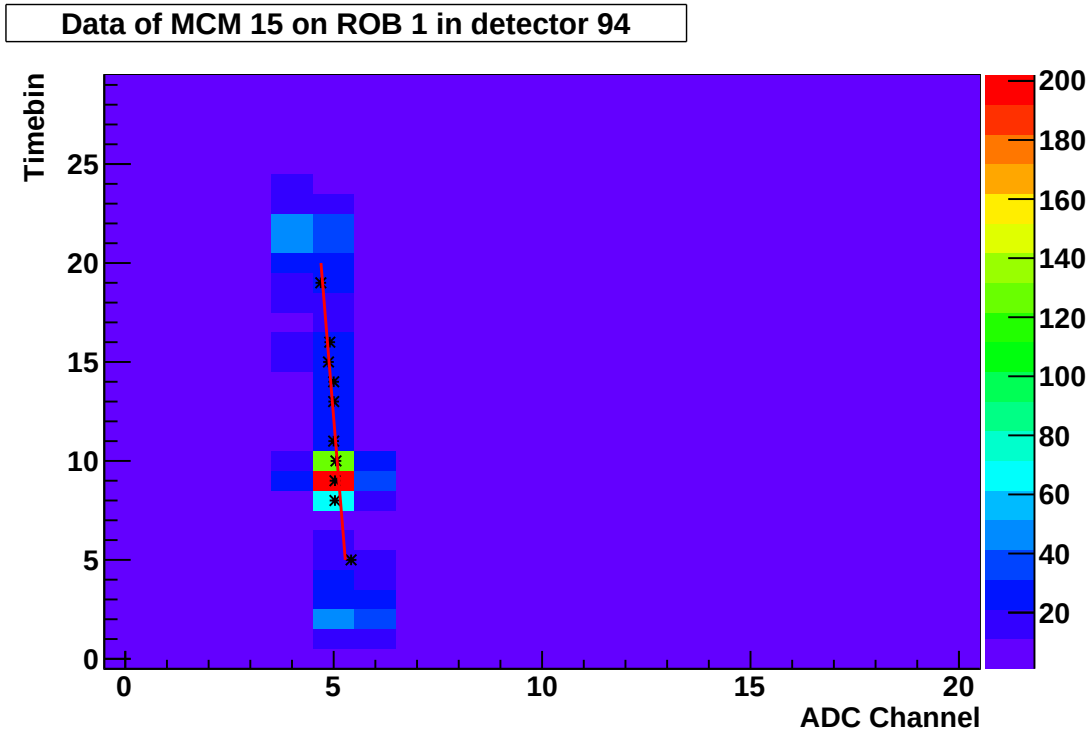

timebin $\leftrightarrow$ radial position
ADC channel $\leftrightarrow$ transverse position

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

$$\Delta y = d_{\mathrm{drift}} \cdot \tan(\alpha_{\mathrm{tilt}}) \cdot \frac{z}{x}$$

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

On-line reconstruction

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    + corrections + $p_\perp$-cut
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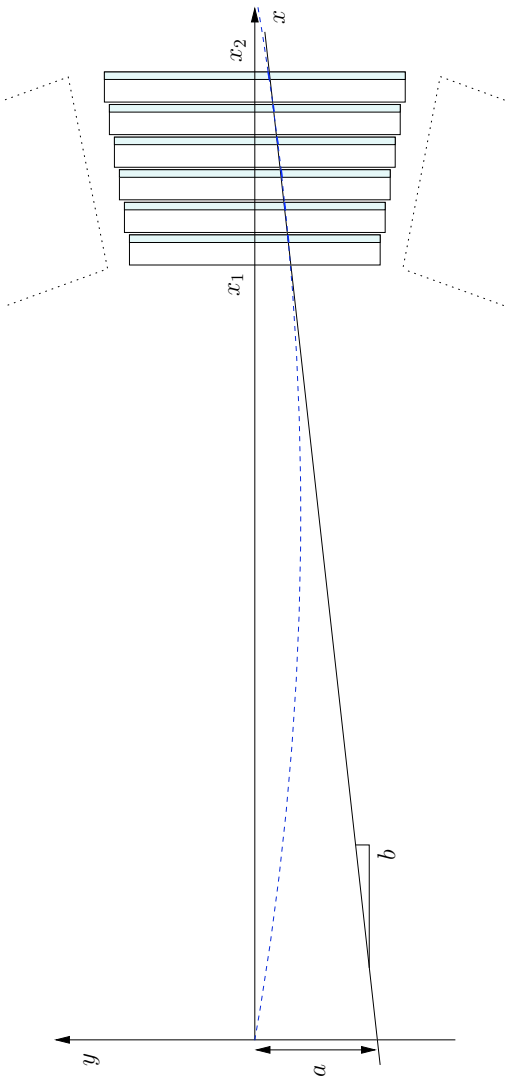

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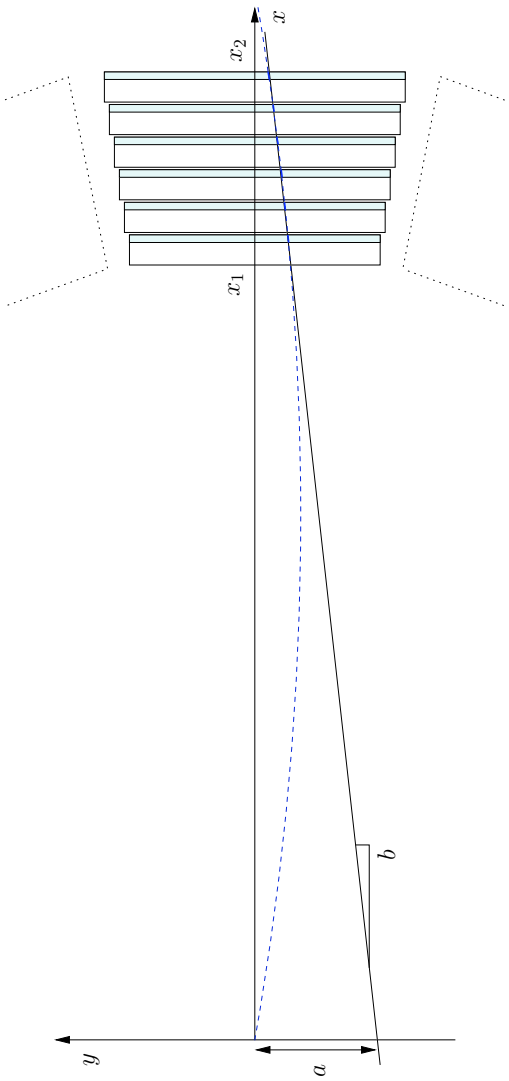
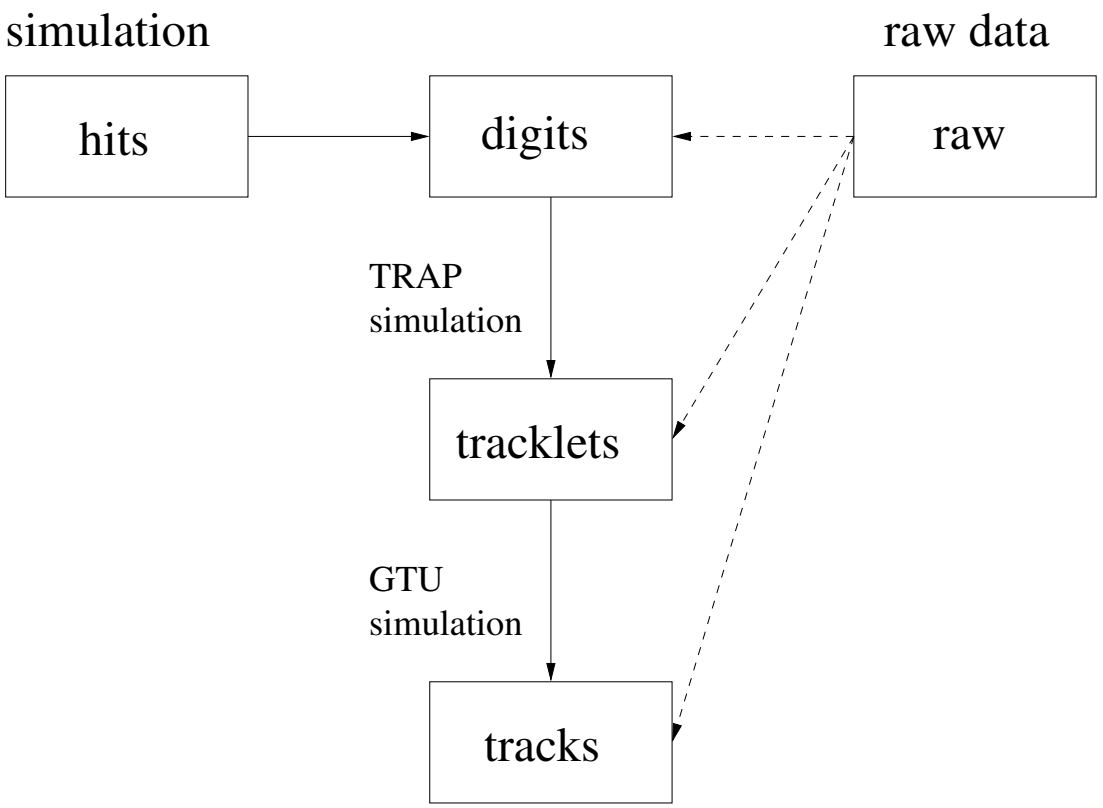
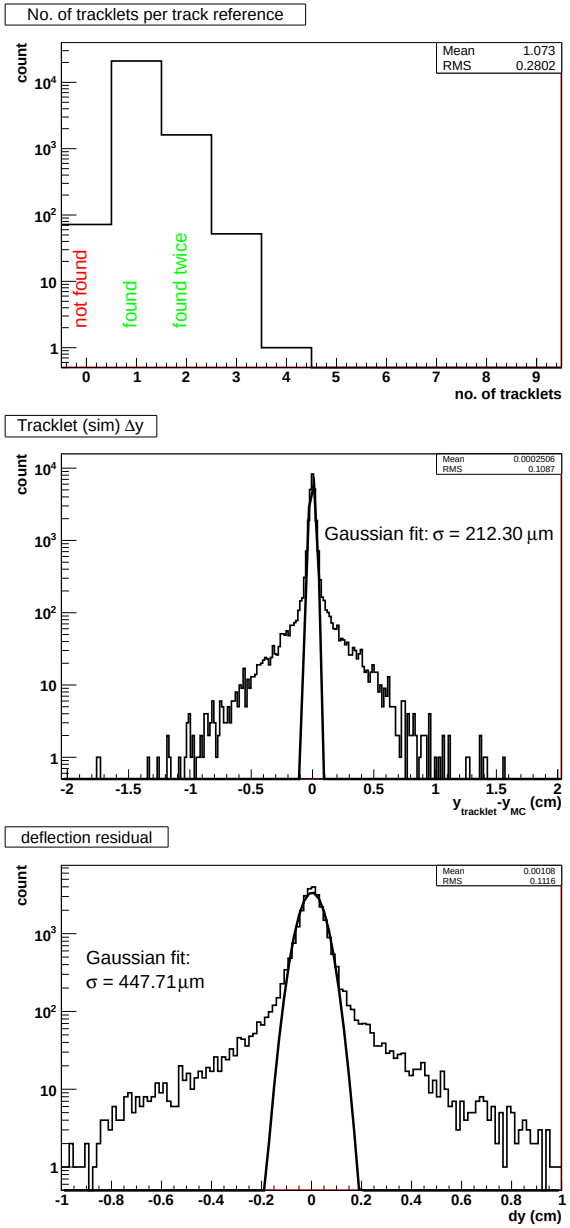


Exact simulation



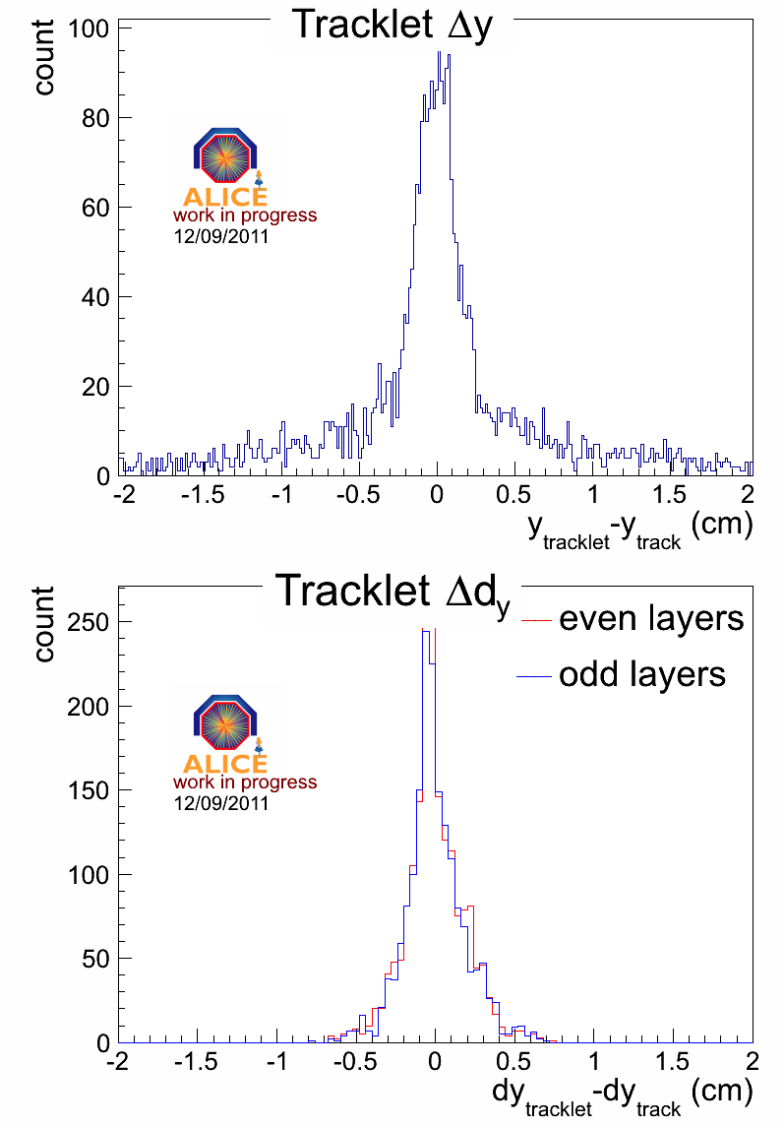
- all calculations done on digitized data which are read out
- allows for detailed re-simulation of the full trigger chain
- simulation of TRAP and GTU

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 $\sim 200\mu\mathrm{m}$
- achieve good deflection resolution of $\sim 400\mu\mathrm{m}$ (without tail cancellation)

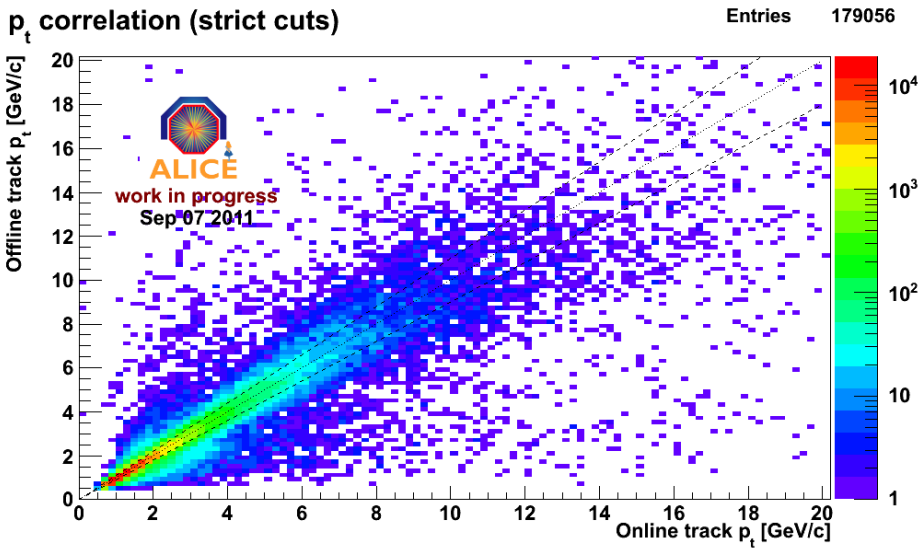
Tracklet performance – data

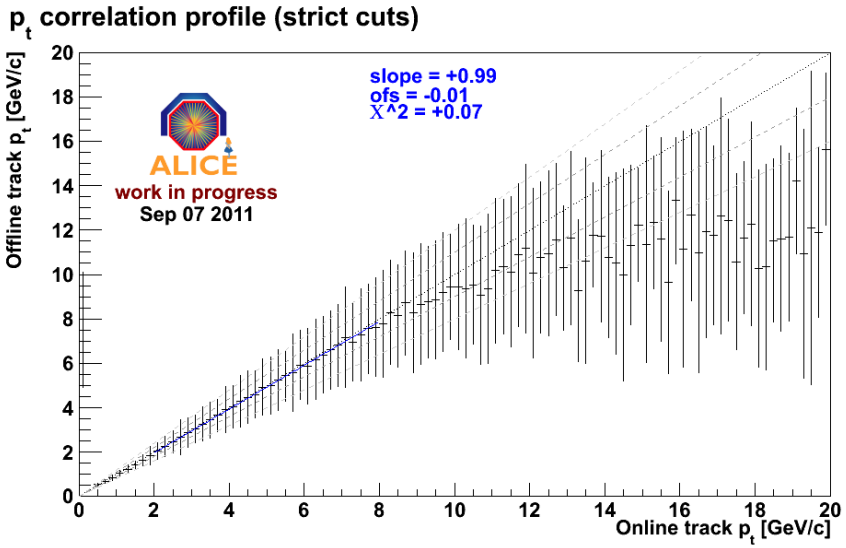


pp @ 7 TeV

- 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

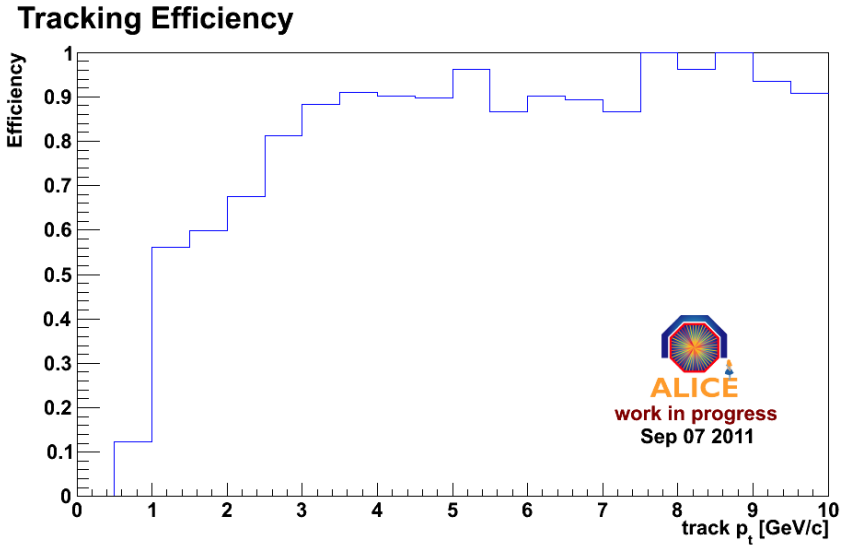
Tracking performance

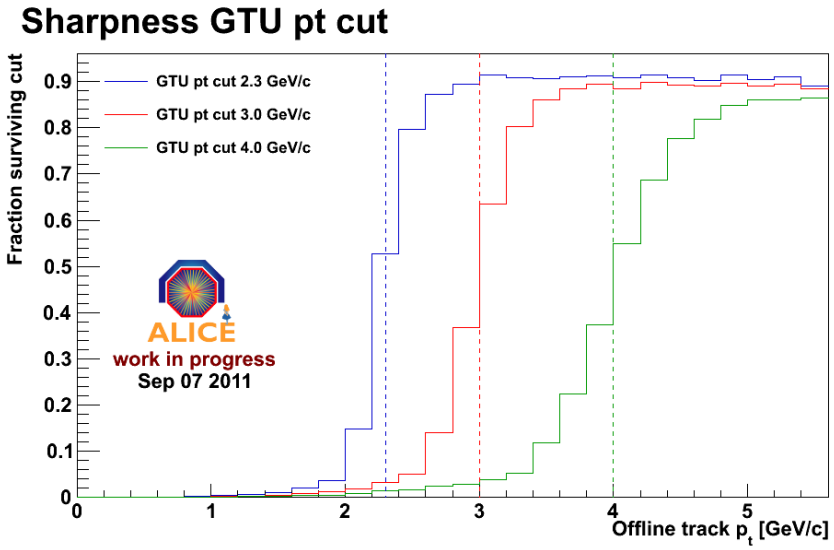




- geometrically match on-line track to off-line track
- compare $p_\perp$
- tracking performs well up to high-$p_\perp$
- deviation from diagonal for very high $p_\perp$ expected from algorithm
- resolution about 15 % to be further improved by FEE tuning

Trigger performance





- efficiency for "good" tracks:

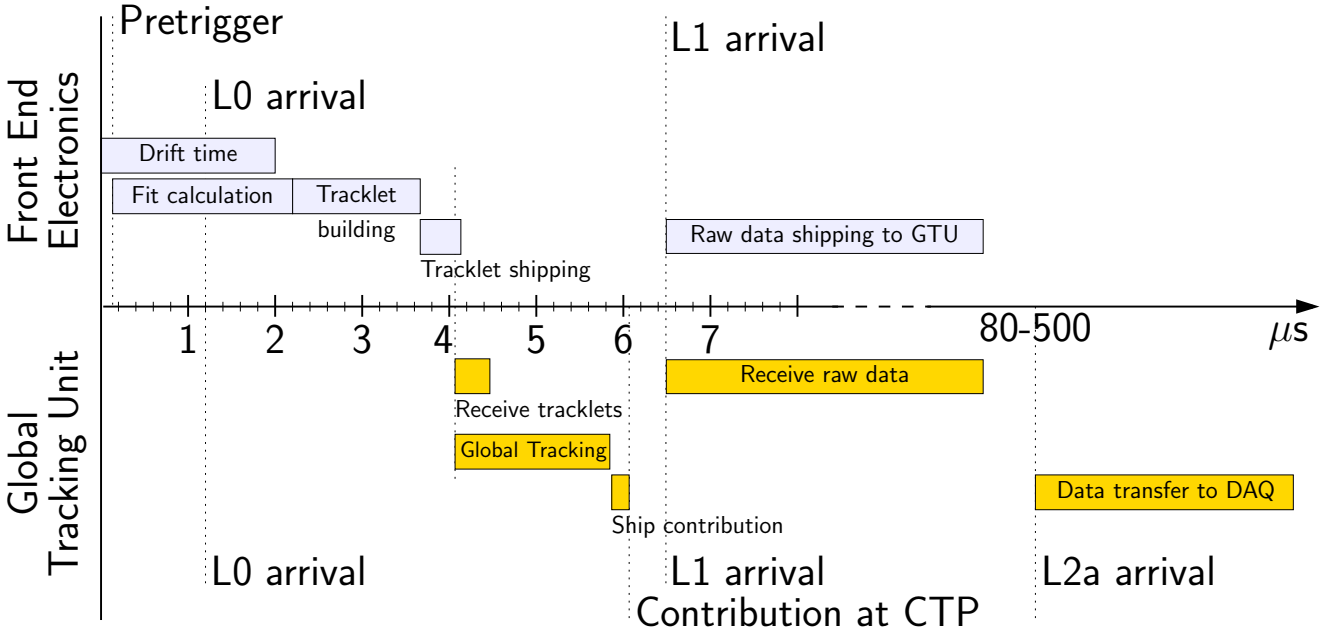
$$\frac{N_{\text{matched}}}{N_{\text{findable}}}$$

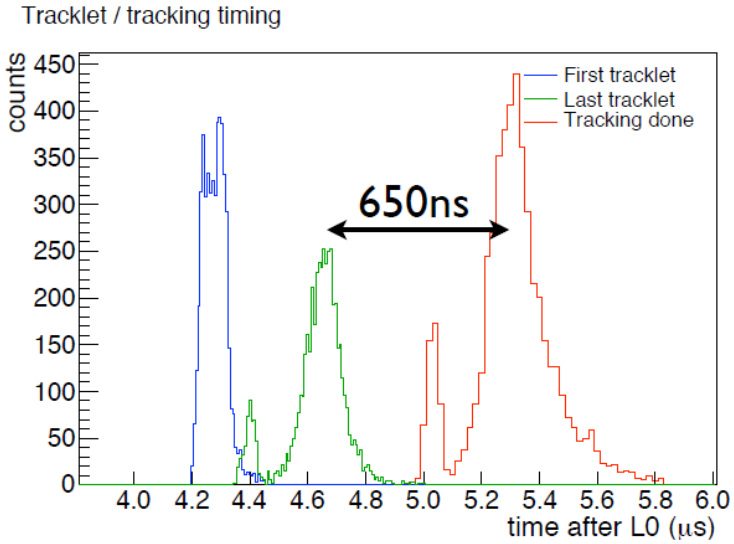
N_{findable}:
off-line tracks with at least 4 TRD tracklets

N_{matched}:
track which is geometrically matched to a findable one

- compare off-line $p_\perp$ when applying cut on on-line $p_\perp$

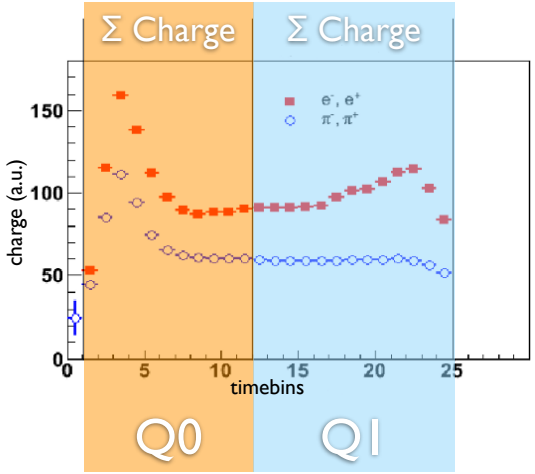
Timing





- processing optimized for low latency tracking starts upon arrival of the first data
- total tracking time depends on multiplicity

$e^{\pm}$ identification – strategy



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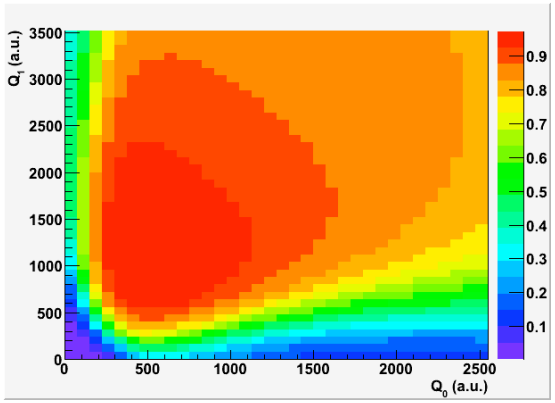


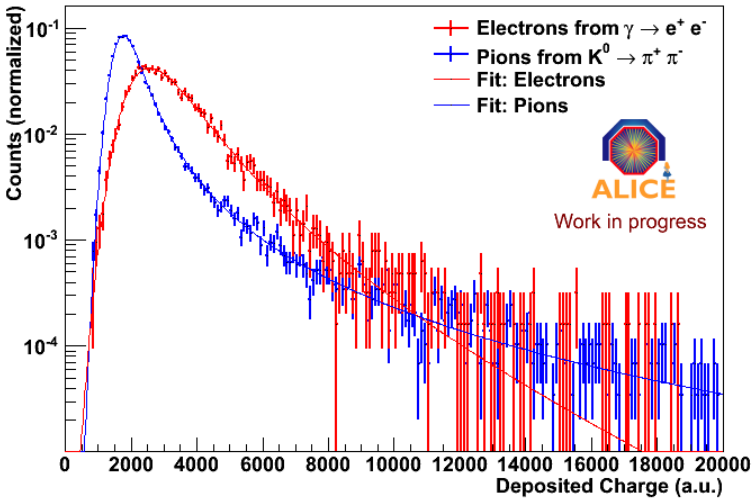
↓

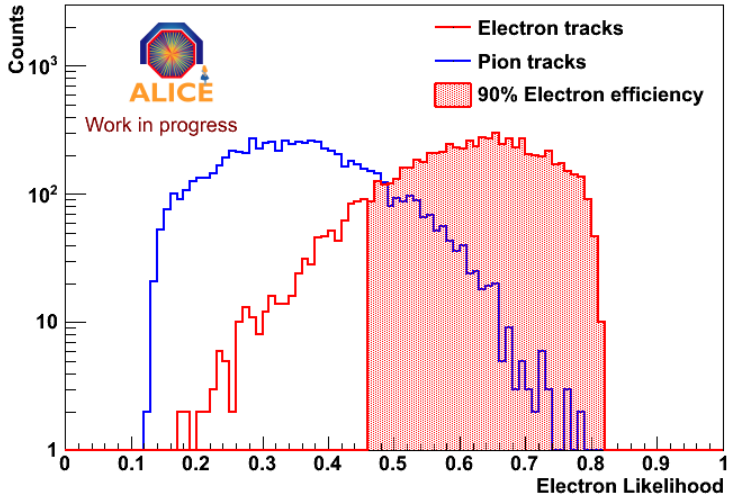
electron likelihood

- 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
$\Rightarrow$ calculate off-line

$e^{\pm}$ identification – reference data





- clean input sample from

$$\gamma \longrightarrow e^+e^-$$
$$K^0 \longrightarrow \pi^+\pi^-$$

- fit charge deposition

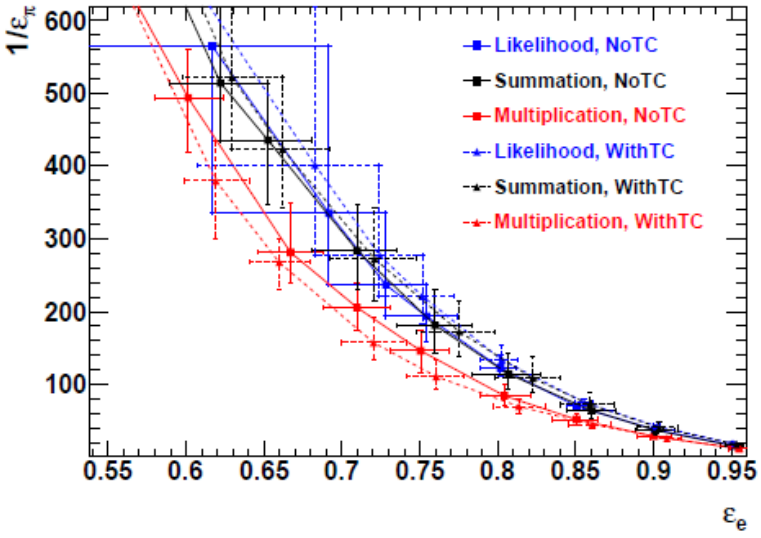
$$(\mathrm{Exp} \cdot \mathrm{Landau}) \otimes \mathrm{Gauss}$$

(s. talk by Xianguo Lu)

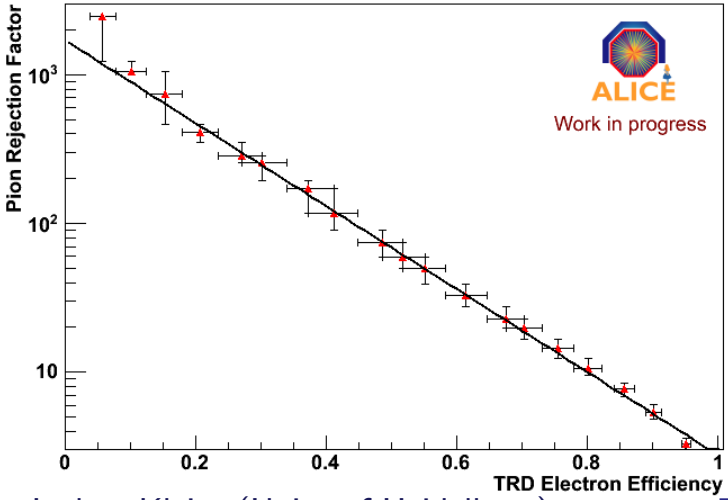
- charge dependent electron likelihood
- define cut to cover wanted fraction of the electrons

$e^{\pm}$ identification – performance

simulation



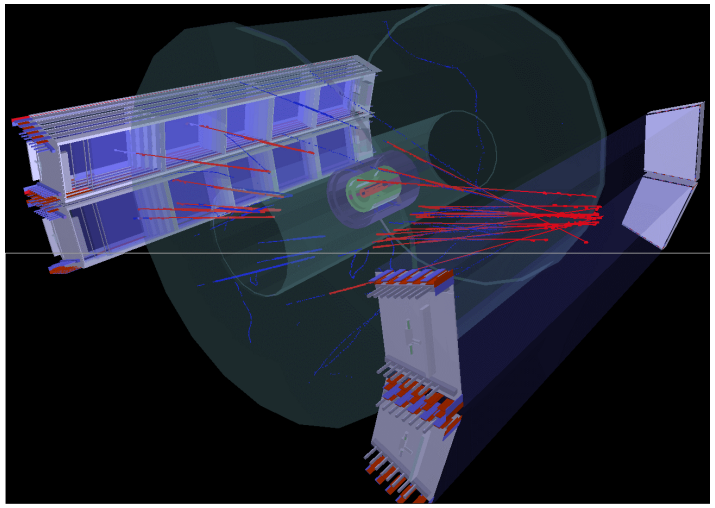
real data



- pion rejection controlled by adjusted electron efficiency
- typical values in simulation:
  for $\epsilon_e = 90\%$: ~ 40
- typical values in real data:
  for $\epsilon_e = 90\%$: ~ 6
  for $\epsilon_e = 80\%$: ~ 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

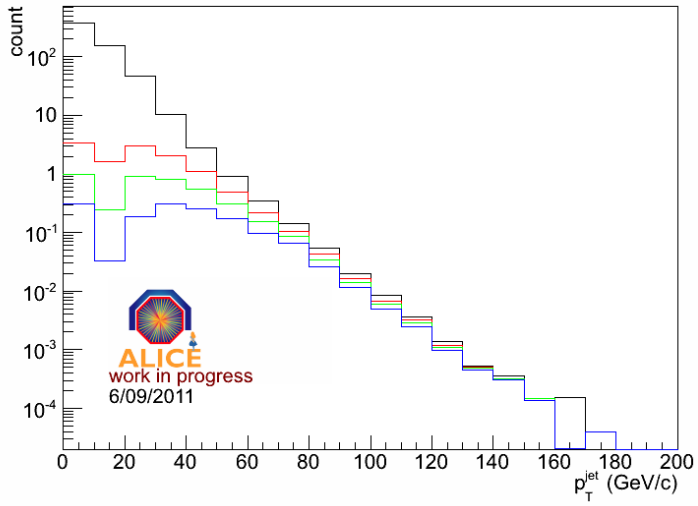
- first version using coincident charge deposition operated since 2008
  all trigger infrastructure already commissioned

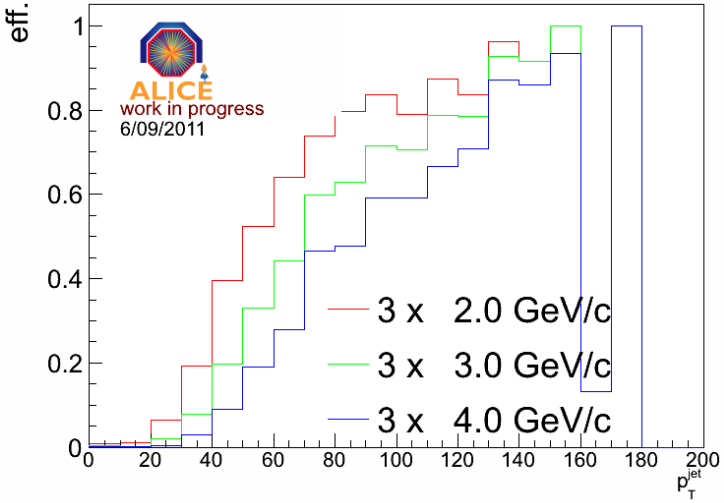
- moved to track-based trigger
  requiring just one track

Jet trigger – Concept

- use on-line reconstructed tracks of charged particles
- TRD stack covers an area in η-φ plane comparable to a typical jet cone ($R \simeq 0.4$)
- 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

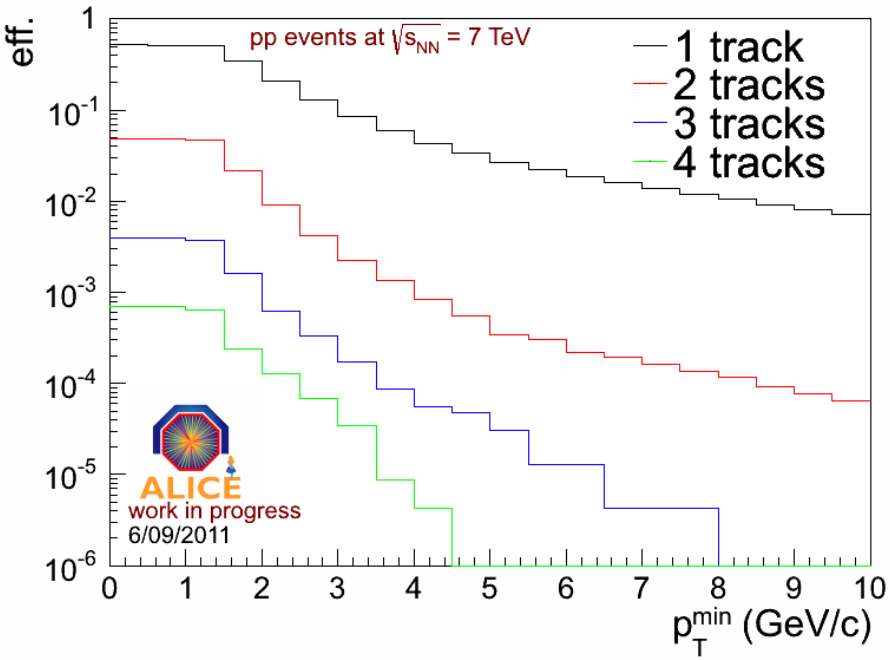
Jet trigger – efficiency from Monte-Carlo





- looking at PYTHIA jets produced in $p_\perp^{\mathrm{hard}}$ 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

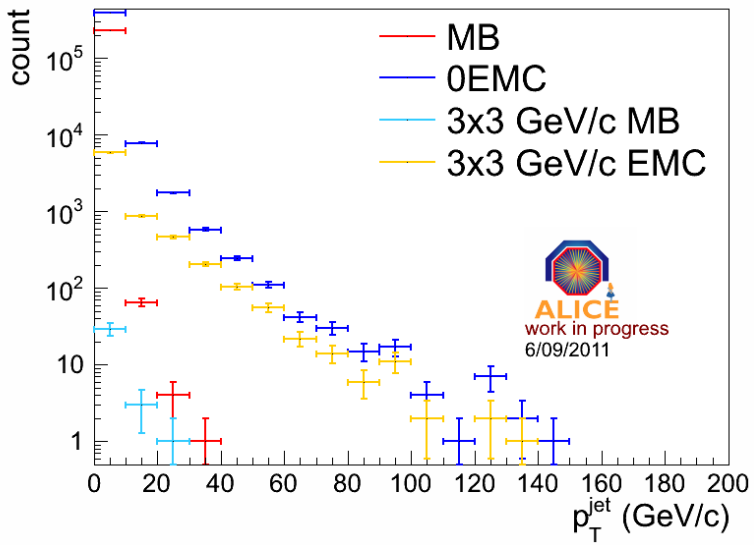
Jet trigger – rejection of min. bias events



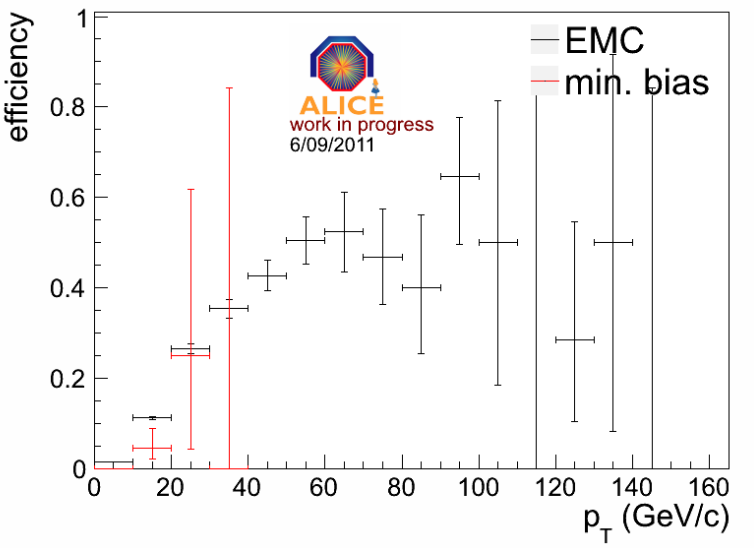
- rejection of min. bias events determined from real data
- good rejection of $\sim 10^4$ for typical threshold
  3 tracks above 3 GeV/c

Jet trigger – raw spectra

spectrum



efficiency



- 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