TRD EDR – Introduction

Overview and specifications for Run3/4

ALICE

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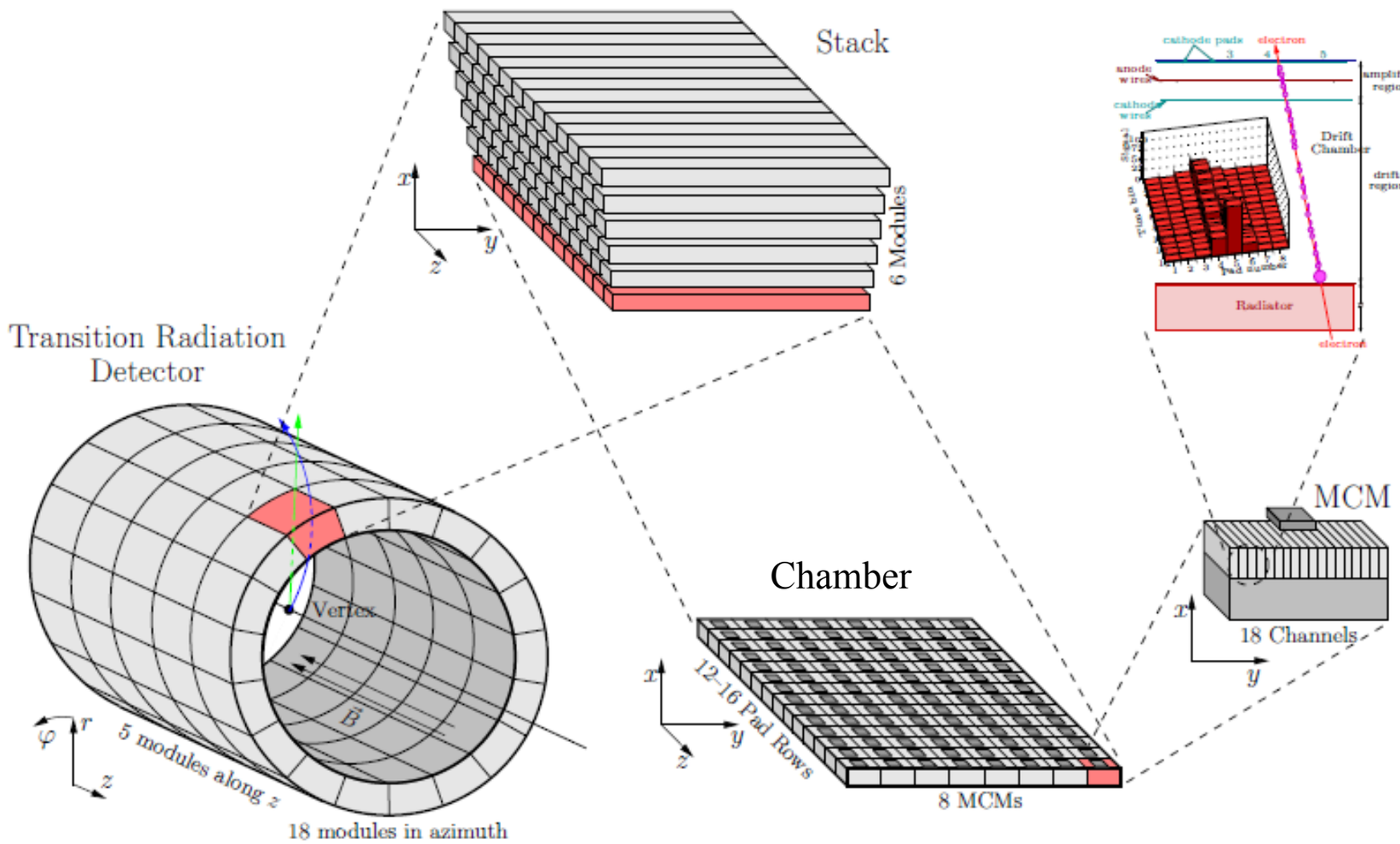
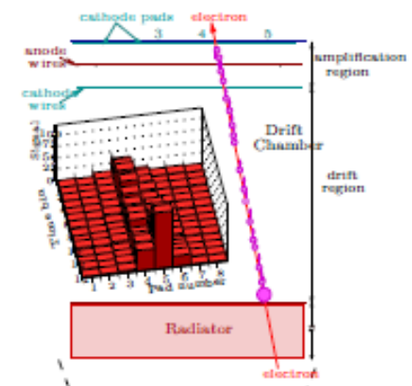
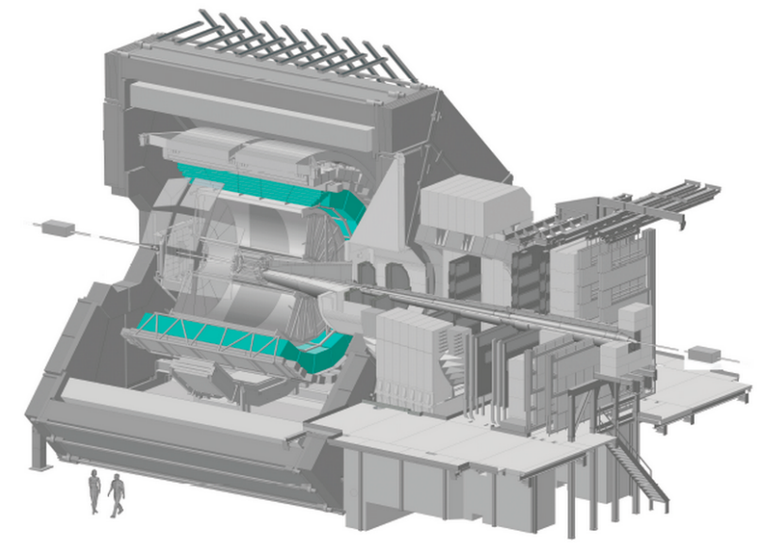
ALICE Transition Radiation Detector



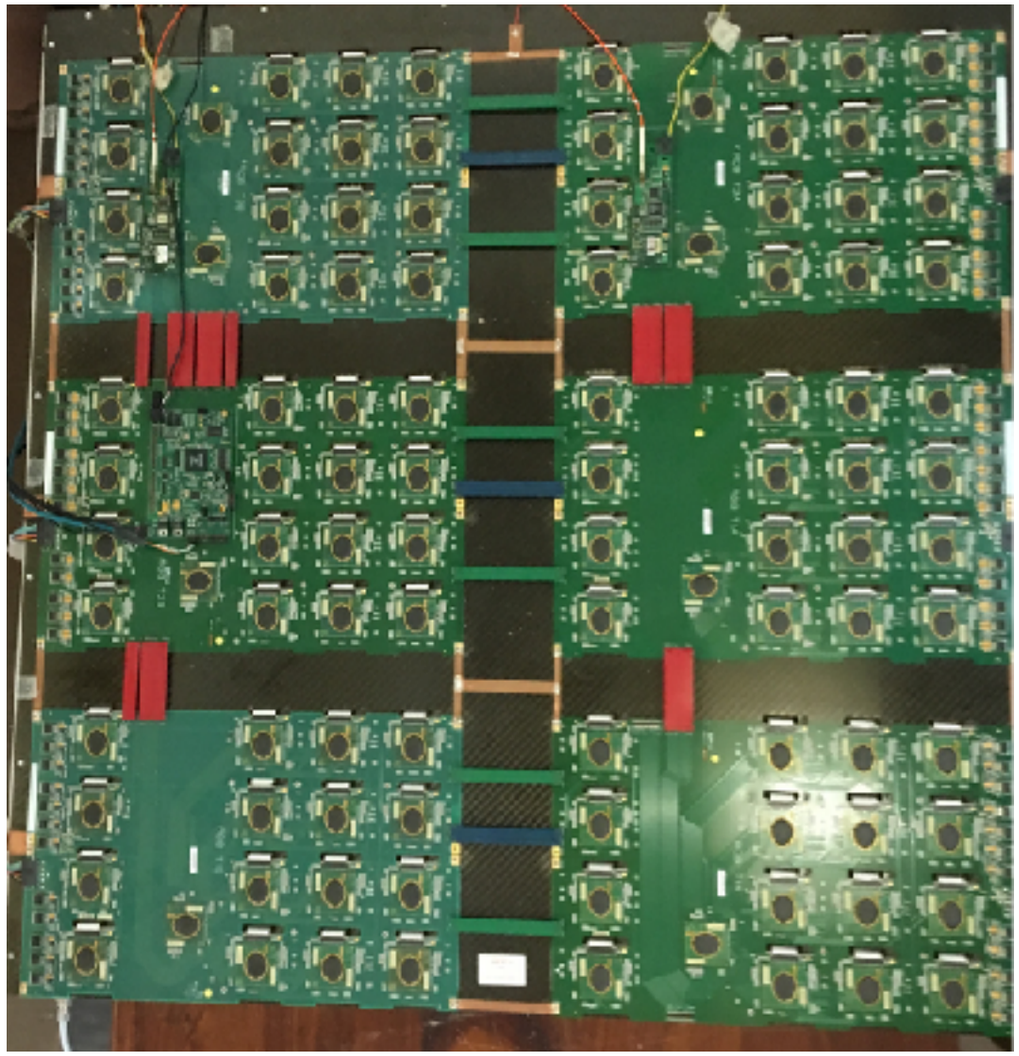




- 1.2 million channels
- 10 MHz sampling rate
- up to 30 samples / event
- 18 super-modules
- 540 read-out chambers
- 1080 readout links@2.5Gbps

Front-End Electronics and Readout Tree

- 6 or 8 read-out boards (ROB) per read-out chamber (ROC)
- 17 or 18 multi-chip modules (MCM) per ROB
  - 16 MCMs connected to pads: ADC, digital filtering, tracklet reco
  - 1-2 merger MCMs
- 2 read-out trees per chamber
  - 3 or 4 ROBs
  - data from 96 or 128 MCMs
  - plus headers
  - *“half-chamber”*
- 1 optical link per per read-out tree
  - 2.5Gbps with 10b/8b encoding



Roles of the TRD

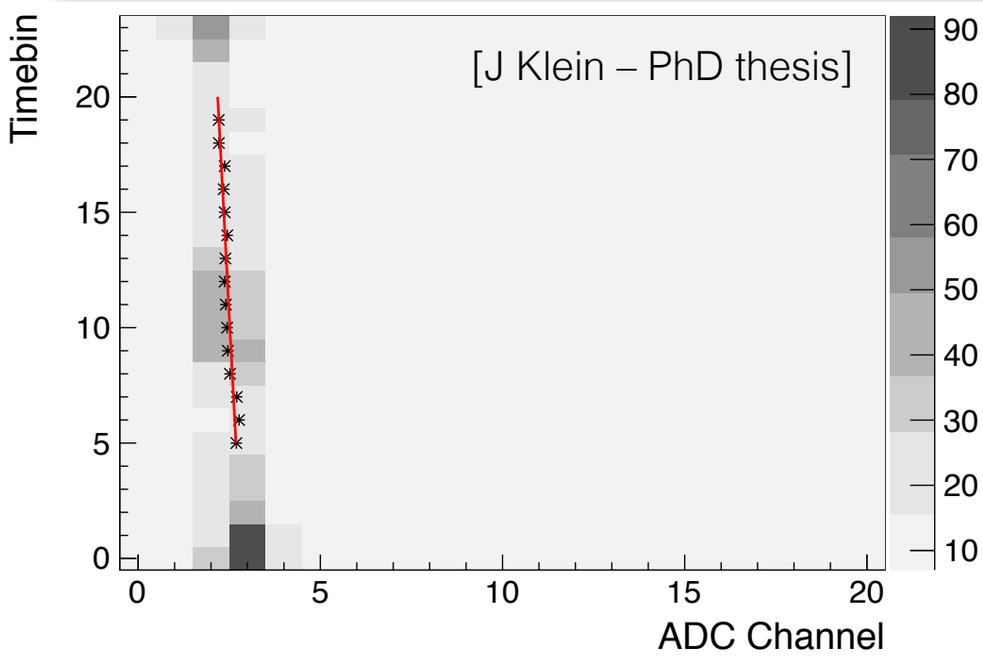
L1 Trigger (6.5μs)

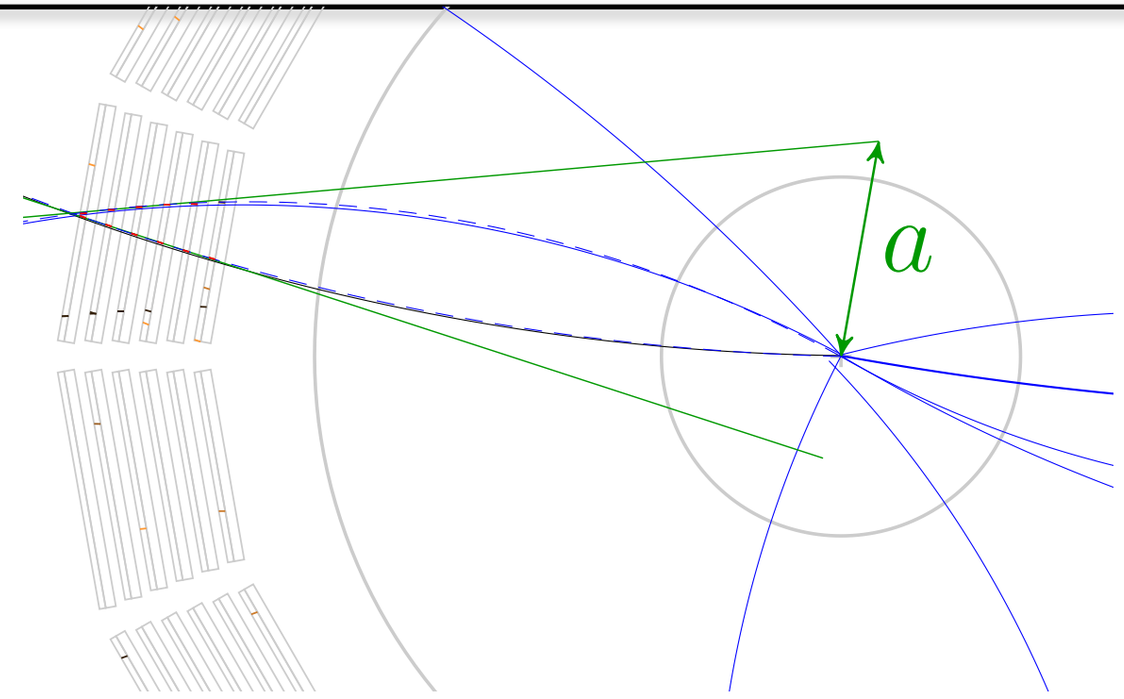
- online selection of
  - electrons
    pion rejection > factor 100
  - jets / high-pT particles
    fast online tracking
  - nuclei
    using dE/dx
- tracking and PID
  - FEE: **tracklets**
  - Global Tracking Unit

Offline Analysis

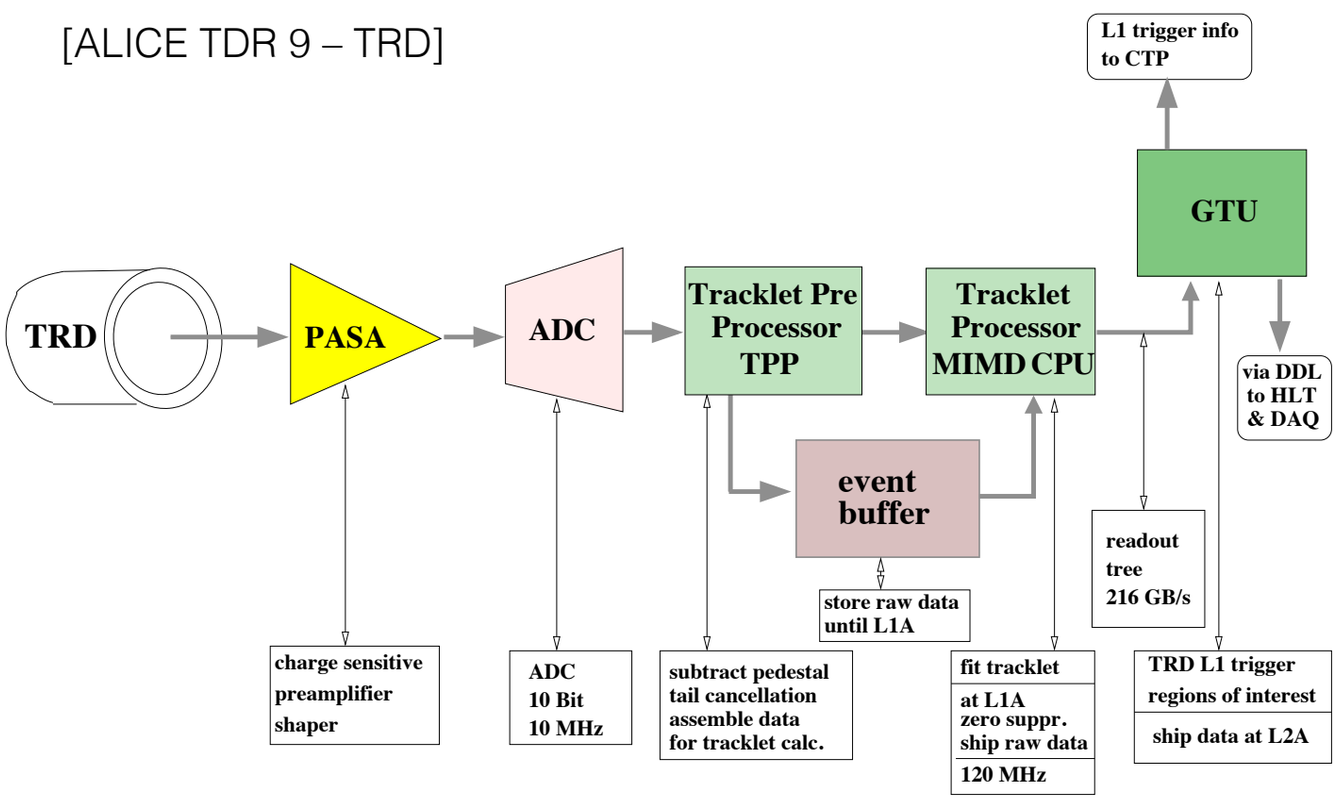
- electron identification
  - transition radiation
  - pion rejection ≈ 100
- tracking
  - lever arm improves p_T resolution for high-p_T tracks
  - correction of TPC space charge distortions
- uses zero-suppressed **raw data**

Online Tracking



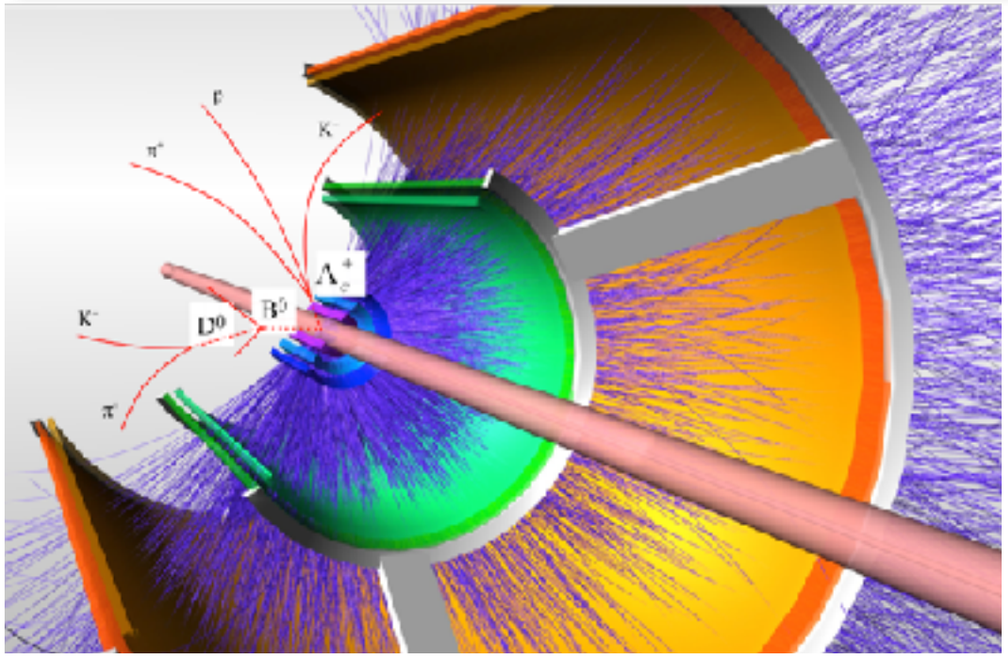


[ALICE TDR 9 – TRD]



- **Front-End Electronics**
  - tracklet: straight line fit in one chamber
  - e-PID based on charge in 2 time windows
- **Global Tracking Unit**
  - tracklets from 6 layers -> track
  - combine PID

ALICE Upgrade

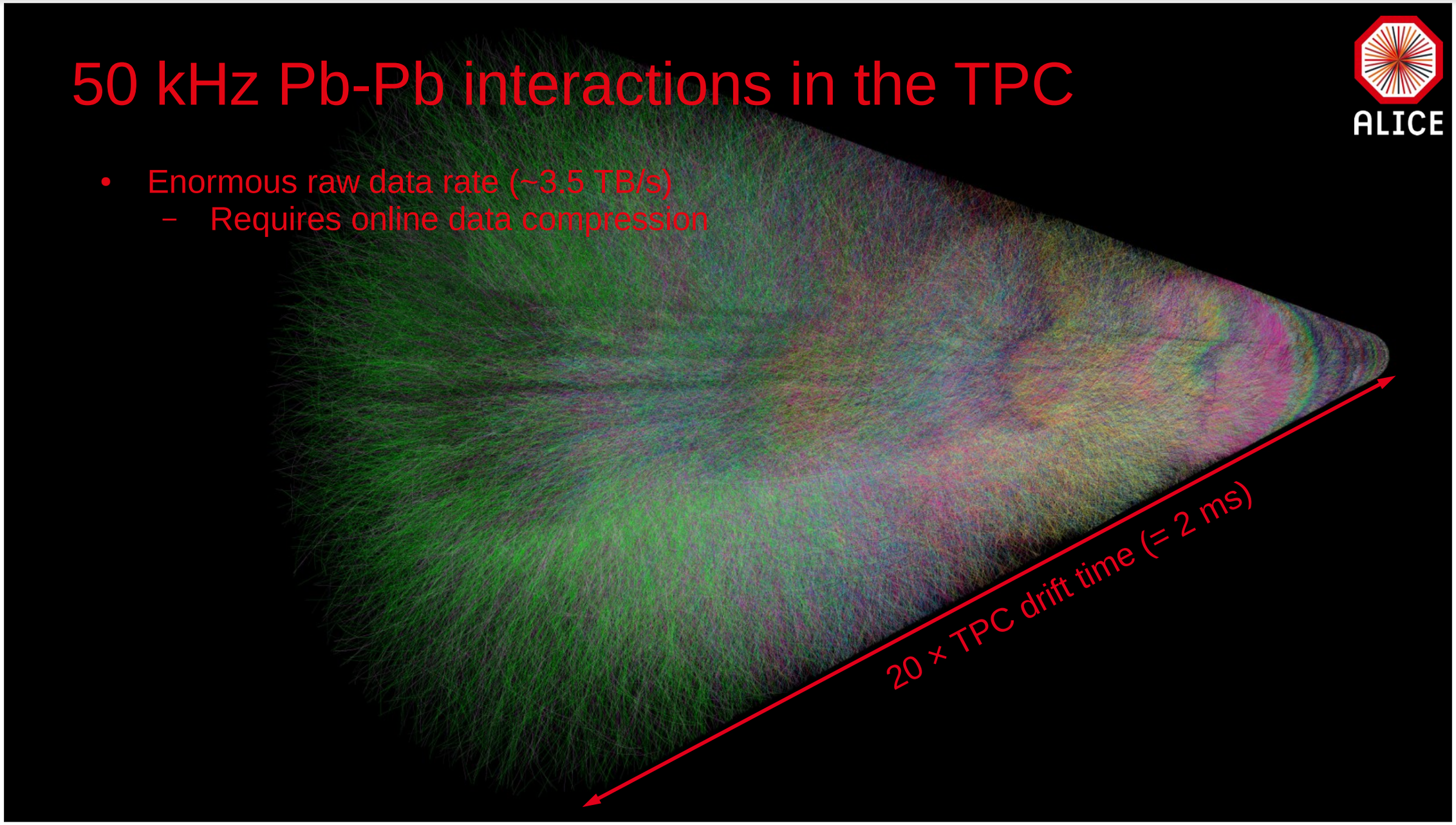


- sensitivity to heavy flavour, leptons and photons down to lowest p_T
- impossible to trigger: rare signals with huge background
- goal: analyse 100x more events

Main upgrades:

- new TPC + ITS
  - continuous, trigger-less readout
  - record everything (after compression)
- new Online-Offline (O^2) system replaces DAQ+HLT+Offline
- new readout electronics
  - handle ITS+TRD data stream
  - **speed up other detectors**

Time Frame



- time frame: full data from ITS + TPC: “all” ADC values with time stamp
- triggered detectors (incl. TRD):
  add as many minbias-triggered events as possible

Roles of the TRD in Run-3

L1 Trigger (6.5μs)

- online selection of
  - electrons
    transition radiation & dE/dx
  - jets / high-pT particles
    fast online tracking
  - nuclei
    using dE/dx
- tracking and PID
  - FEE: **tracklets**
  - Global Tracking Unit

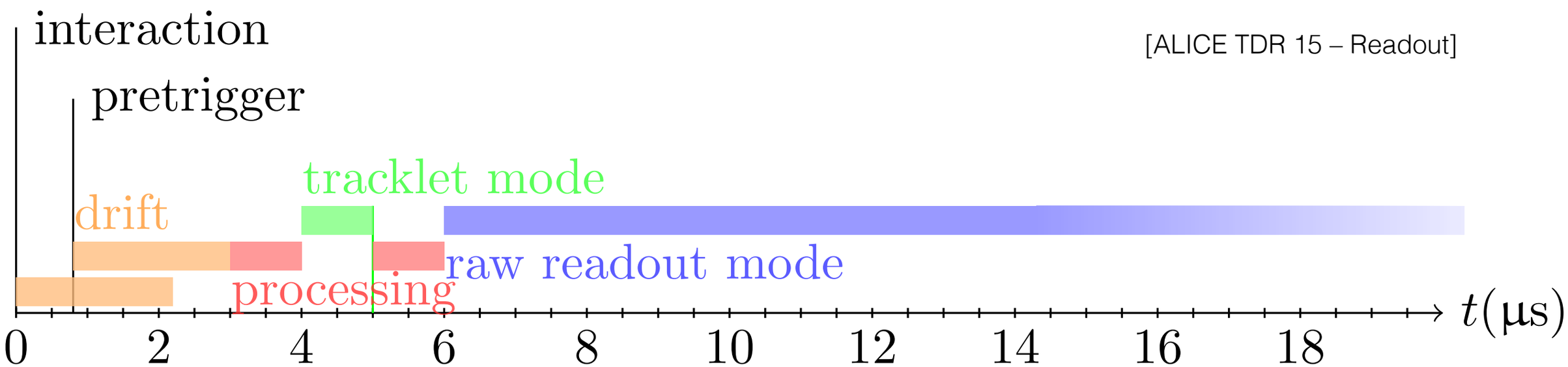
obsolete
no triggers foreseen in Run 3

Offline Analysis

- electron identification
  - transition radiation
  - pion rejection ≈ 100
- tracking
  - lever arm helps for high-pT tracks
  - calibration of TPC
- uses zero-suppressed **raw data**

not feasible -> tracklets

Readout Modes



[ALICE TDR 15 – Readout]

- **tracklet mode (used for trigger in Run-1/2)**
  - low latency, fully buffered, no handshake
  - dead-time < 8µs: drift time+processing (ca. 4µs) + data transfer (0-4µs)
  - limited by buffer size: 256 tracklets per half-chamber (4 per MCM)
- **raw read-out mode**
  - no buffering, requires handshaking, higher latency
  - handshaking adds 8.32µs overhead
  - dead-time at least 20–30 µs:
    drift time+processing (ca. 4µs), handshaking (8.32µs), data transfer (4µs/kB)
  - supports full or zero-suppressed readout of ADC data

TRD Scenarios for 50 kHz Pb-Pb

Goal: process maximum fraction of 50 kHz Pb-Pb

- current limitation of few kHz readout rate

New front-end electronics – not an option

Zero-suppressed raw data readout:

- read-out rate limited by FEE dead-time (>20μs)
  compare with interaction rate: 50 kHz in Pb-Pb, 100 (200) kHz in pp
- high data volume: estimated 63 GB/s for min-bias Pb-Pb
  (50 kHz interaction rate, 66% dead-time, 3.7MB/event)

Tracklet-only readout

- use low-latency, small volume trigger data for offline processing
- short dead-time (<8μs), sample 70–80% of events at 50kHz
- limited to 256 tracklets per half-chamber / 4 tracklets per MCM

Tracklet Data Format

Run-1/2 Data Format

tracklet / trigger data

8 bit	4 bit	7 bit	13 bit
PID	z	y defl.	y position
PID	z	y defl.	y position
PID	z	y defl.	y position
PID	z	y defl.	y position

+ raw ADC data

Run-3 Format

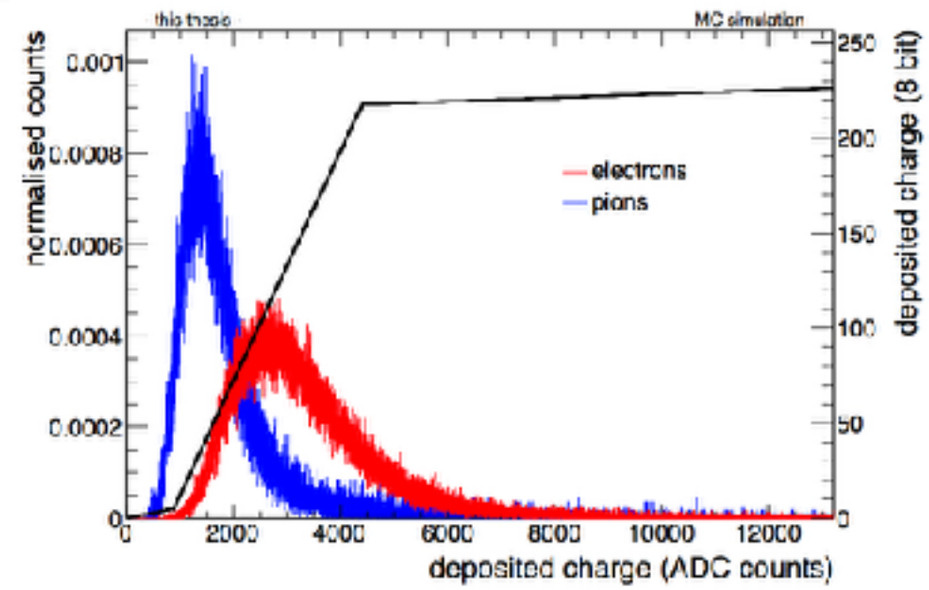
8 bit	4 bit	7 bit	13 bit
PID	z	y defl.	y position
PID	z	y defl.	y position
PID	z	y defl.	y position
extra PID	extra PID	extra PID	
10 bit	10 bit	10 bit	

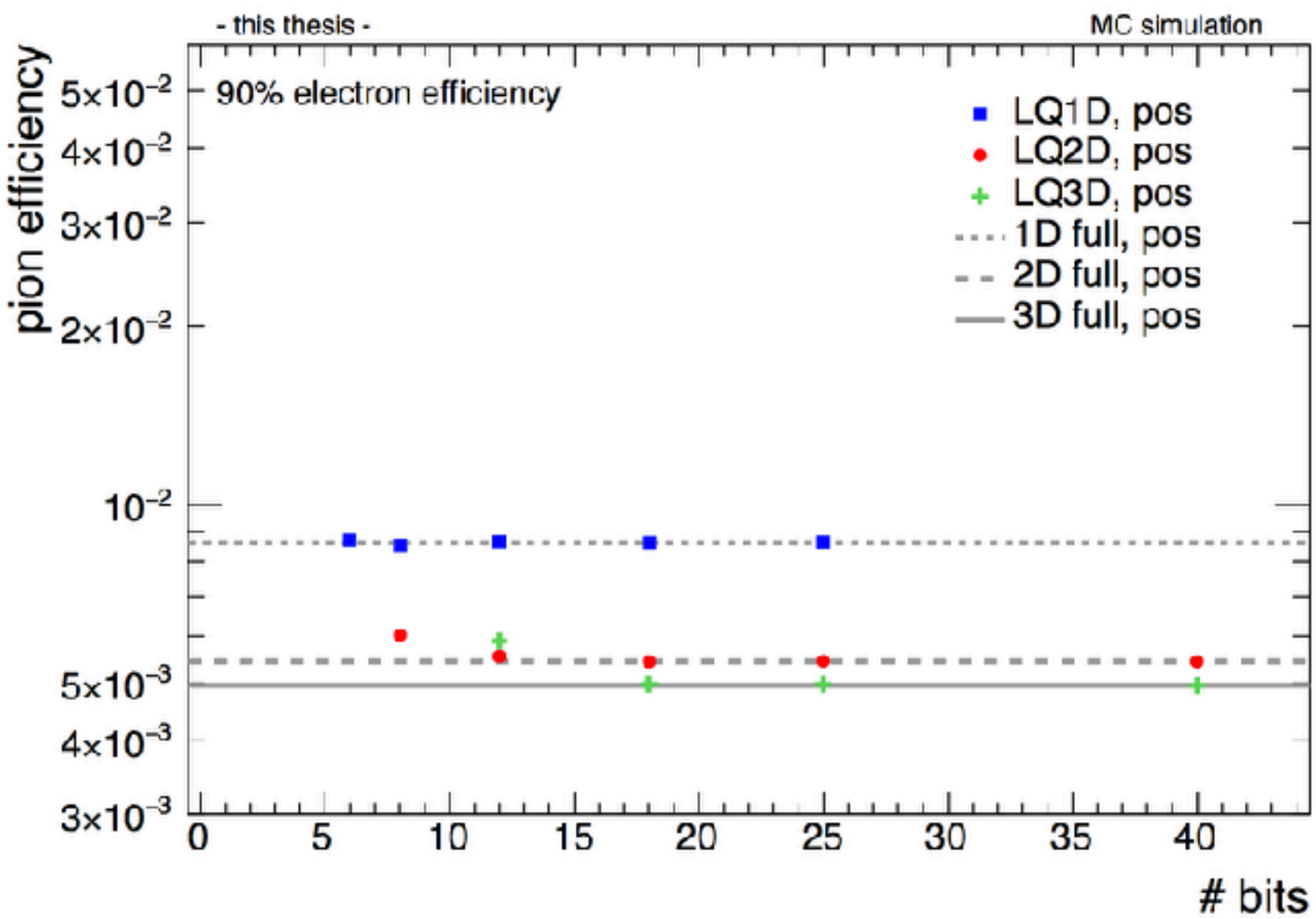
- very limited space: 128 bits for up to 4 tracklets per MCM
  - only 18 bit for PID in Run-3 (8 bit in Run-1/2)
  - max of 3 tracklets (4 in Run-1/2) per MCM
  - position resolution (13 bit, 140µm granularity) shown to have small impact on tracking
- **raw data still required for calibration / QA**
  - small fraction of events / negligible data volume

PID with limited precision

Optimize usage of available bits:

- Tri-linear lookup table
- Fine granularity in sensitive region
- Coarse mapping in tails





Optimum performance from ~ 6 bits per slice

Good performance of LQ2D with 8 bits

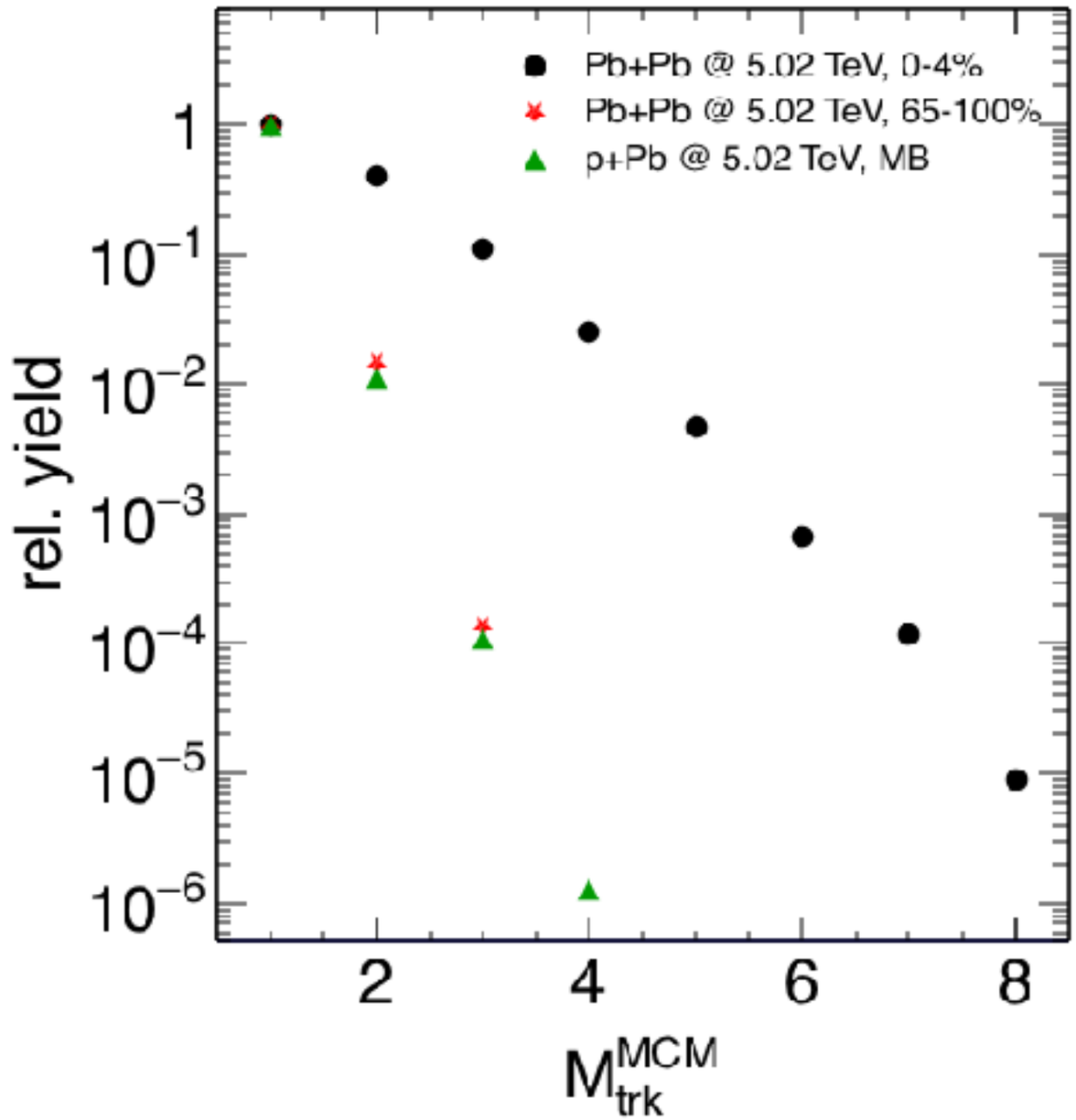
Pion efficiency <1% in MC!

Outlook:

- apply to real data
- sensitivity to calibration

Tracklets per MCM

- estimate effect of limitation to 3 tracklets
  - shown: number of offline tracks passing through 1 MCM
  - only 3 tracklets accepted more will be lost for offline
- loss negligible in peripheral Pb-Pb and p-Pb
  - less than 10^{-6} of MCMs affected
  - also applies to pp
- visible effect in central Pb-Pb
  - 1.7% of MCMs have 4 or more tracklets
  - < 0.5% overall loss
    (1.7% of MCMs lose 1 of 4 tracklets)



Rate Estimates from TDR

- full / partial raw read-out for comparison
- tracklet data allows for highest readout rates
  - assuming average occupancy of 25% and 50% (conservative)
  - results in 6-8 μs dead-time (for the slowest optical link)
  - accept 70-80% of events (35 kHz) at 50 kHz interaction rate
  - data rates of 10-20 GB/s for full TRD

	interaction rate [kHz]	Accepted rate [kHz]	Accepted fraction [%]	deadtime [%]	data volume [Gb/s/sector]
tracklet read-out only					
avg. deadtime 6 μs	50	38.5	76.9	23.1	4.73
	100	62.5	62.5	37.5	7.68
	200	90.9	45.5	54.5	11.17
avg. deadtime 8 μs	50	35.7	71.4	28.6	8.78
	100	55.6	55.6	44.4	13.65
partial raw data read-out	50	23.3	46.5	53.5	7.8
full zero-suppressed ADC data	50	16.6	33.2	66.7	27.9

[ALICE TDR 15 – Readout]

Summary

- upgraded TRD will use tracklet readout
  - 6-8μs dead-time, small data volume < 1kB/event
  - impact on PID, tracking has been studied
  - requires change read-out electronics, data formats, reconstruction

- raw read-out required for calibration and QA
  - fixed fraction (1/1000) of all events

- conservative estimates from TDR
  - about 35 kHz events sampled at 50 kHz interaction rate
  - small influence of busy time on event rate
  - data rate of less than 10 GB/s expected

- good physics performance expected for conservative estimates

Backup

Tracklet Data Volume

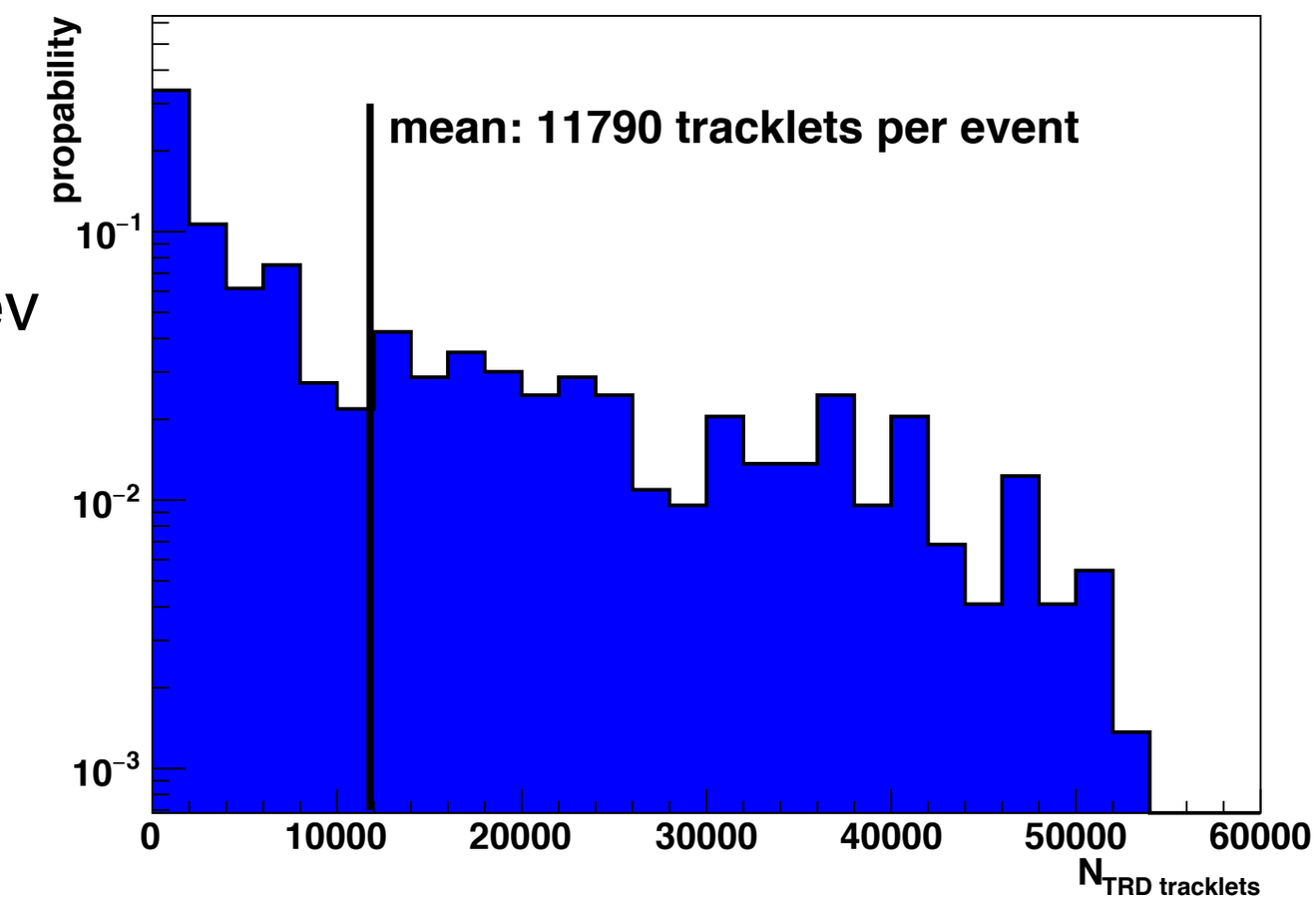
Assumption in Readout&Trigger Upgrade TDR:

- two scenarios: occupancy of 25% or 50%
- 10–20 GB/s for 50kHz interaction rate / 35–40 kHz RO rate

Data from Pb-Pb

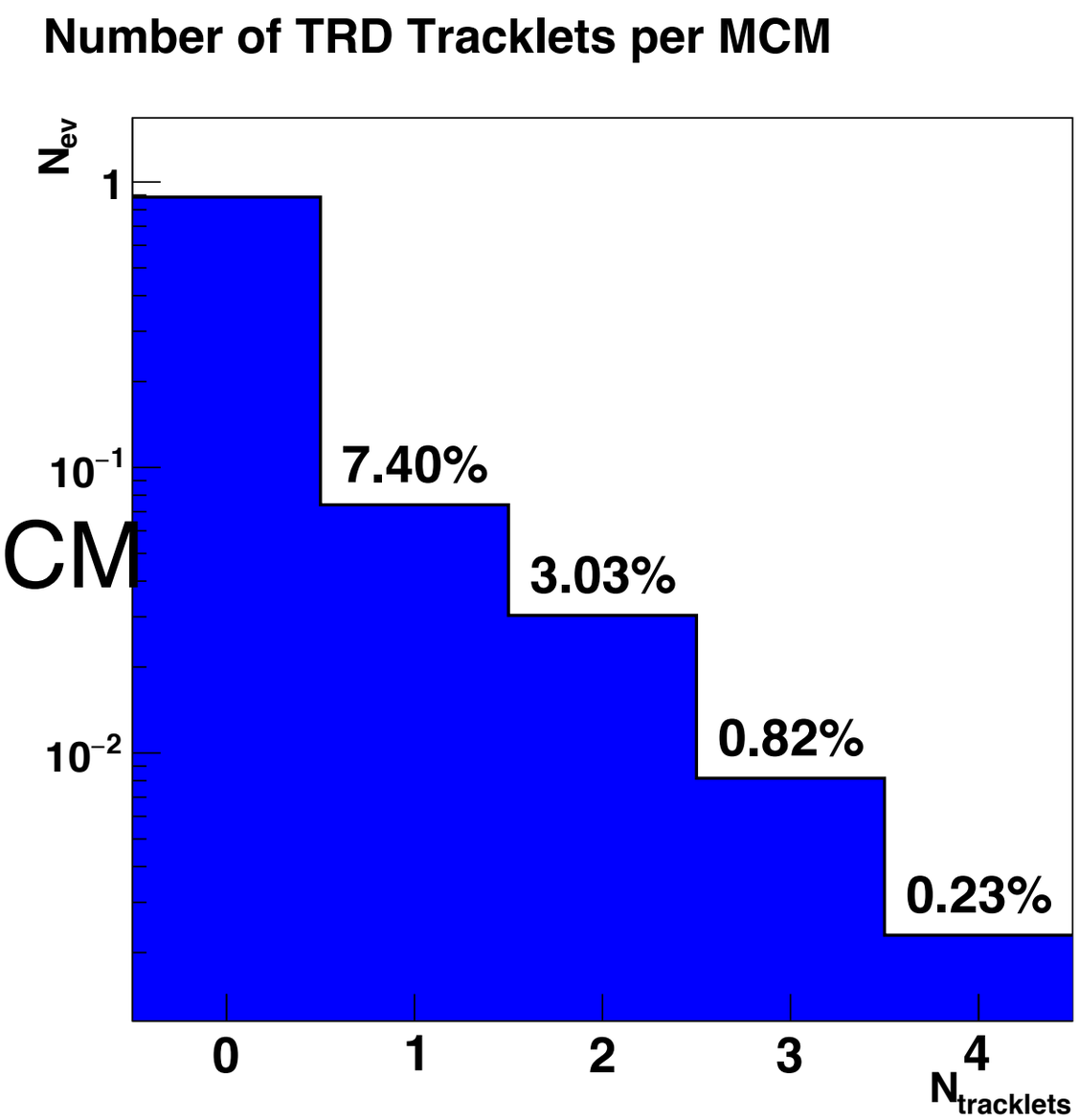
- run 246392, LHC15o
- max 55000, avg 12000 tracklets per event
- theoretical max: 1044 x 256 = 267264 tracklets / ev
- avg occupancy ≈ 4%

- assuming 4 bytes per tracklet
  → 50 kB / ev
  → 2.4 GB/s @ 50 kHz RO rate

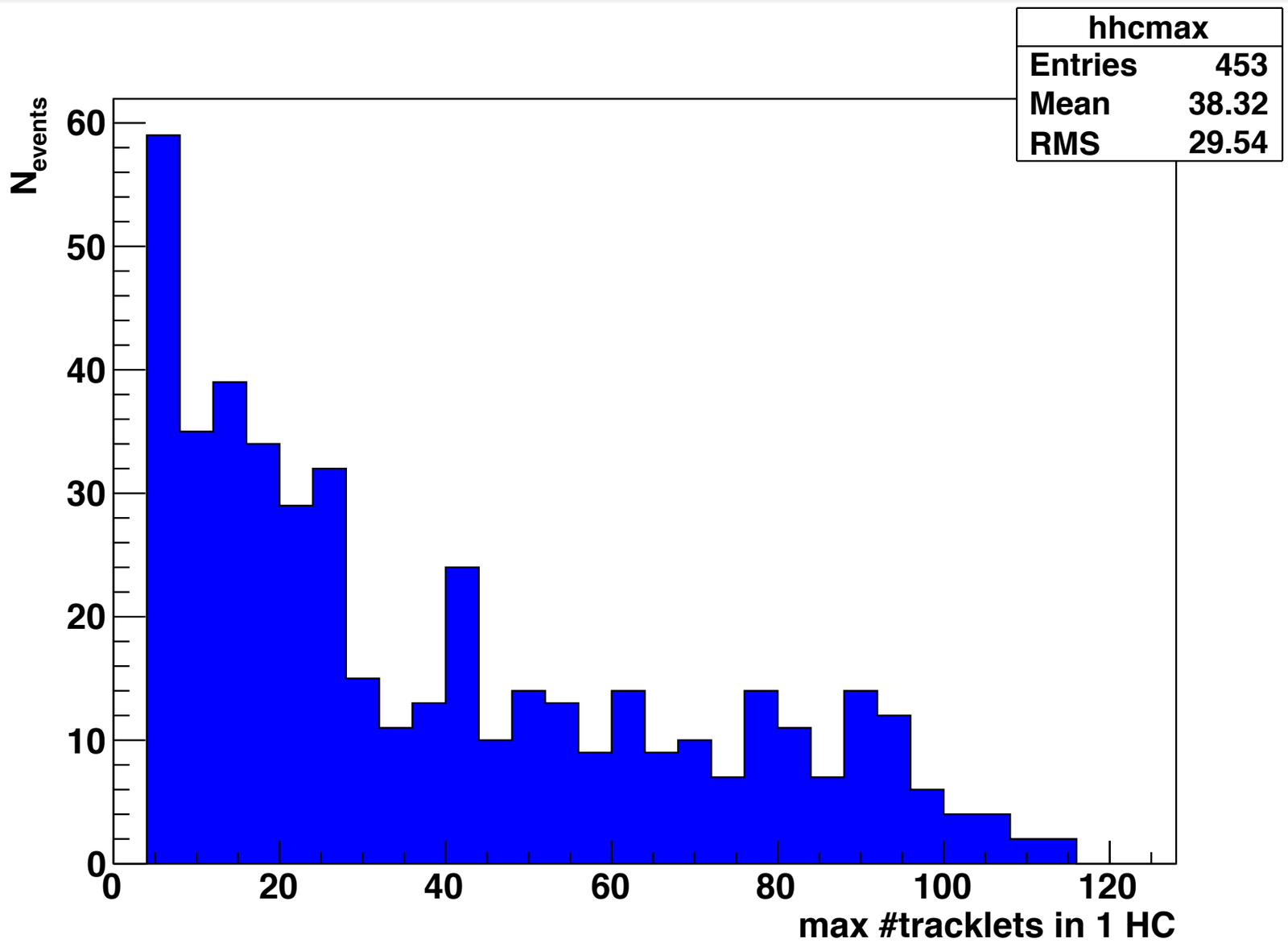


Estimated Data Volume

- estimate based on LHC15o run 246392
- previous readout scheme:
  - 12000 tracklets
  - 48kB/ev
  - 2.4 GB/s @ 50kHz
- new MCM data format:
  - 1 additional dword per MCM
  - ca. 19000 dwords
  - 75kB/ev (+50%)
  - 3.8 GB/s @ 50kHz



Tracklet Occupancy per Half-Chamber



- significant variation between events (correlated with centrality)
- less than 50% occupancy in most central collisions (theoretical max: 64 MCMs x 4 tracklets/MCM = 256 tracklets)
- data transmission time up to 2 µs (theoretical max. 4 µs)

Tracklet Occupancy vs Centrality