technische universität dortmund

SFB 876 Providing Information by Resource-Constrained Data Analysis

Project C5

Real-Time Analysis and Storage of High-Volume Data in Particle Physics

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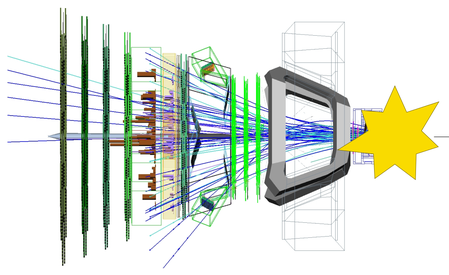
Problem



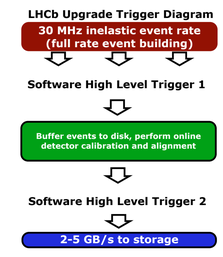
Trigger → Stripping → Analysis

GPU / FPGA — **_DeLorean_** — **ARM cluster**

hybrid trigger — integrated stripping/analysis — CRC Phase 3

LHCb experiment

CRC Phase 2



GPU-Based Track Trigger

- **LHCb Upgrade**
- 5× higher particle density per event → new tracking detectors
- Pure software trigger with 40× input rate; 4 TB/s dataflow
- Highest quality trigger decisions require full reconstruction
- Goal: free CPU resources with GPUs/FPGAs for tracking

DeLorean

- Data-intensive scans on petabytes of data
- Diverse search predicates / complex analyses
- Extremely rare events (probability: $10^{-12} \sim 10^{-15}$)

Methodology

Alternative Architecture Approaches

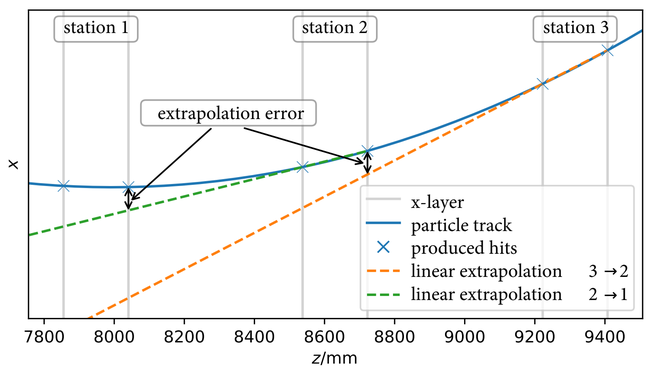
- Adapt Tracking Algorithm to GPU and ARM [Breß et al. SIGMOD 2016]

SciFi Tracker

- 3 stations with 4 layers
- Layer rotation 0°, +5°, -5°, 0°
- 250 µm scintillating fibres
- 2D hit information
- Resolution < 100 µm

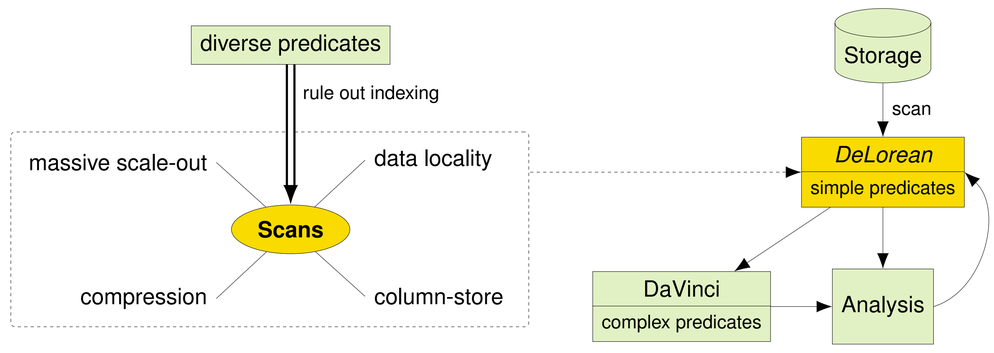
New GPU Algorithm

- Combine hits from first and last layer
- Parallel treatment of all hits
- Combine all matching micro tracks
- Add hits from the middle layer for 3 information



Database Technology for LHCb

[Kußmann et al. BTW 2017, Lindemann et al. HardBD 2018]



***DeLorean* framework:**

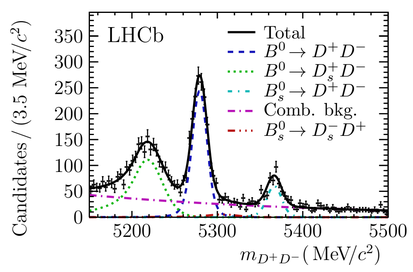
- Column store + lightweight compression
  → Reduce **scan volume**
- Scalability, parallelism
- ~~Stripping~~ → **ad hoc querying**
- Applicable to many types of scientific data
  - *E.g.*, genomic data [Dorok et al. DASP 2017]

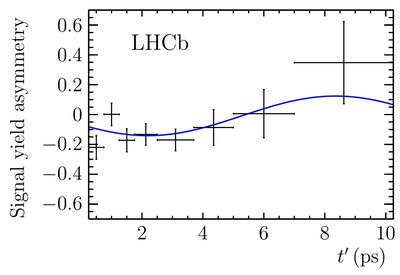
C1

Results

Sample Analysis

Analysis of *CP* violation in $B^0 \to D^+D^-$ decays





- Analysis of Run I data
- ML based selection with Boosted Decision Trees

[LHCb, PRL 117 261801]

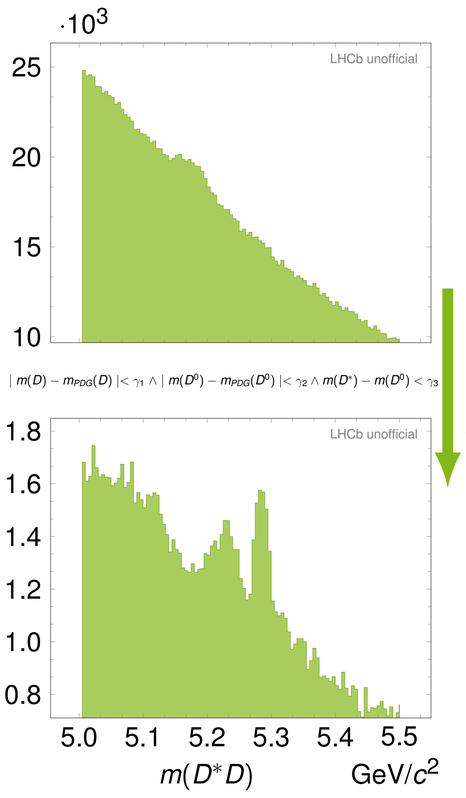
Unfolding with DSEA

- Cooperation within the CRC
- Unfolding based on kinematic variables
- Demonstrated with Monte Carlo data
- Will be used in future analyses

C3

DeLorean @ Work

$B^0 \to D^{*\pm}D^{\mp}$ candidates

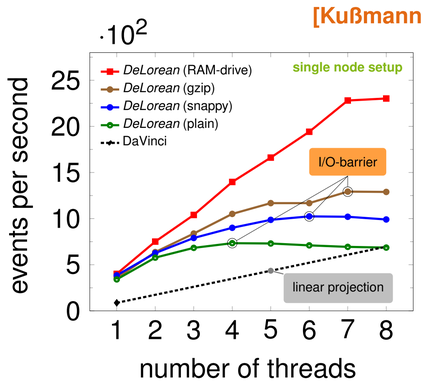


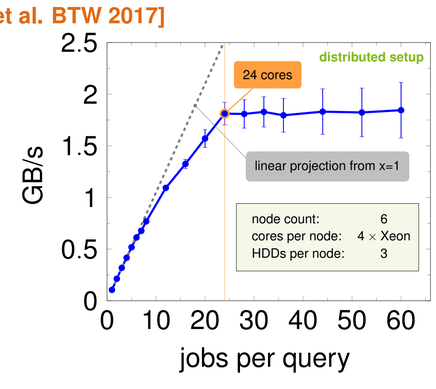
DeLorean

Performance Characteristics

DeLorean

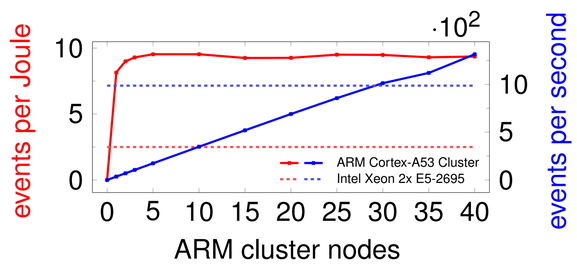
[Kußmann et al. BTW 2017]





- high scan efficiency
- good scaling behaviour

ARM Cluster



- better energy / performance ratio

[Görtz et al. SKILL 2017]

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Lehrstuhl für Experimentelle Physik 5