Connecting the Dots
and
Software Trigger + Event Reconstruction CWP working group

David Lange

April 4, 2017

Connecting the Dots workshop in Orsay

- CTD indico timetable

- The main focus of the workshop is on pattern recognition and machine learning algorithms devoted to the reconstruction of particle tracks or jets in high energy physics experiments

CMS-ers presenting at CTD

- L. Gray : 4D trackers
- A. Morton: FPGA based track finder at L1 for HL-LHC
- G. Fedi: L1 track trigger for HL-LHC CMS w/ AM/FPGA
- M. Zientek: L1 tracking at HL-LHC CMS w/ tracklets
- E. Brondolin: Performance of HL-LHC CMS tracking
- F. Pantaleo: New track seeding techniques for CMS
- F. Sikler: Techniques for efficient track reco in very high multiplity events
- M. Lefebvre: Parallelized kalman-filter track reconstruction

Themes

- Tracking strategies for future/upgraded experiments
- Track trigger plans and opportunities
- Tracking R+D: studies motivated by both hardware evolution (or revolution) and novel (to HEP) algorithmic approaches
- Vertex reco / particle id via (D)NN and other ML techniques

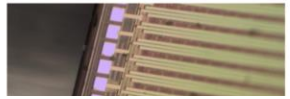
Some examples from Connecting the Dots

- Tracking triggers for HL-LHC

The Seven Requirements for Future Track Triggers

- highly granular pixel
  - → 3D tracking and vertexing
  - → reducing ambiguities
- little material
  - → reduces MS, secondary interactions and thus confusion problem
- good timing
  - → resolve bunch crossing
- high efficiency @ low noise
  - → fewer tracking layers
  - → reducing ambiguities
- fast readout capabilities
  - → high track rates
- radiation hardness
  - → high track rates
- affordable
  - → large sensitive areas

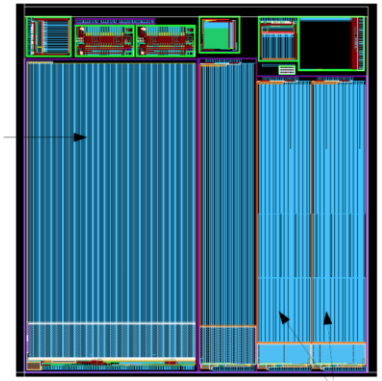
A.Schöning, Heidelberg University 21



Recent Monolithic Pixel Chip Submission

AMS aH18 process
- HV-CMOS 180 nm
- being diced right now

Mupix8 for Mu3e (+LHC)
- 80 x 80 µm² pixel
- comparator in periphery
- **track trigger outputs**



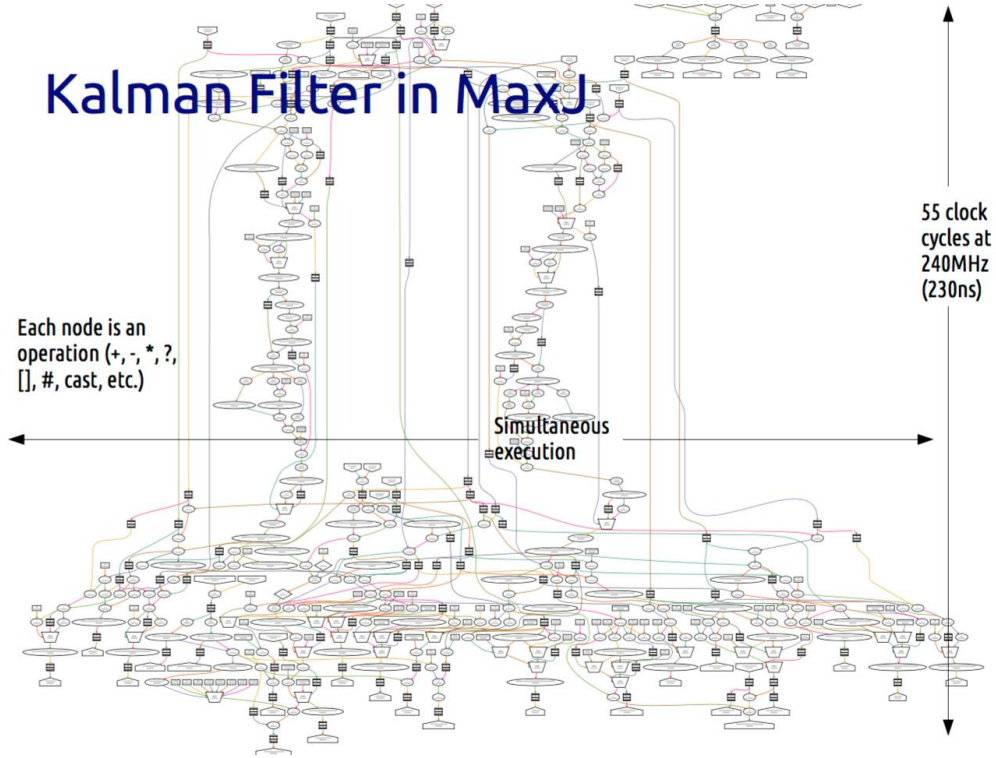
23mm

main designer I.Peric (KIT)

dedicated test structures
- 40 x 130 µm² pixel
- comparator in pixel
- **track trigger outputs**

A.Schöning, Heidelberg University 30 Connecting the Dots, Orsay, March 2017

- New techniques for tracking: e.g., FPGA Kalman filter

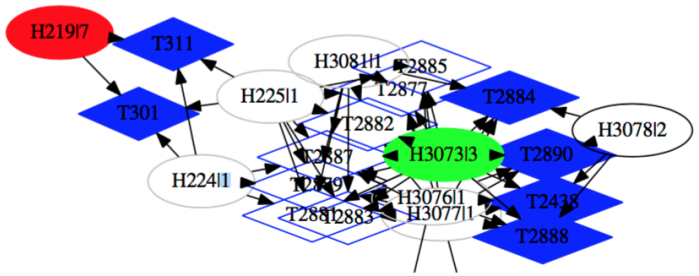


Some examples from Connecting the Dots

- Graph based track building

Executive summary – some thoughts

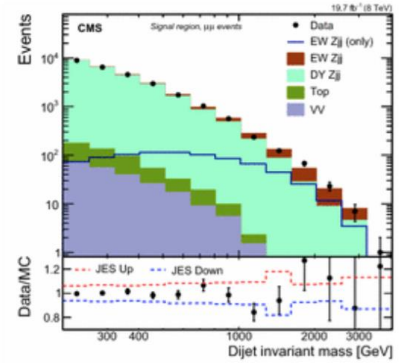
- How to select the best set of tracks?
  - ☺ keep concurrent choices open; several hit-track assignments
  - ⇒ **treat the hits and track candidates as a (bipartite) graph**
  - – the graph can be highly connected; but has vulnerable components
  - ☺ disconnect it by looking for *bridges* and *articulation points*
  - – in the end each hit must belong to at most one track
  - ⇒ **solve subgraphs, decision tree, deterministic single-player**
  - – maximize the number of hits on track, then minimize $\sum \chi^2$



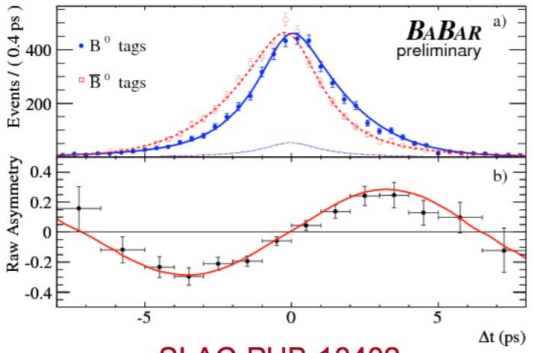
- Machine learning approaches to tracking and identification

SLAC

- **Weak supervision** is a new paradigm the **class proportions** in high-level observables in order to use **unlabeled data** to extract **discriminating information** from poorly modeled or unknown **low-level observables**.



Eur. Phys. J. C (2015) 75: 66



SLAC-PUB-13402

CWP

Software trigger and event reconstruction CWP working group

- Several clear motivations for a merged working group
  - Many issues are in common today and for R+D towards the 10 year horizon
    - Event complexity and increased throughput are big challenges
    - Experiments moving towards final analysis data sets produced in the trigger
  - Frequently have common software stacks (eg, in CMS)

- The WG has formed in the January/SDSC CWP workshop and met again at the end of the CTD workshop
  - Good participation from ATLAS/CMS/LHC-b/LC/FCC*/ALICE*/Intensity frontier* [*= at SDSC only]

CWP : Software trigger / event reconstruction WG Issues

- Main challenges identified (I)
  - Large increases in event complexity and event rates:
    - Push to reduce data volume and processing time per event
  - Overabundance of signal:
    - Drives event rate, trigger menu complexity
    - Approaches to inspect (and store) information from all (or more) events (eg, scouting)
  - Detector upgrades towards high granularity.
    - Good examples are CMS HGCal and timing layer. Need to develop algorithms with high quality physics and computational performance
  - Computing technology evolution:
    - (How) can we make time-critical algorithms as agnostic to computing hardware as possible?
    - Are Some algorithms more sensitive to hardware properties than others? Choosing to evolve algorithms vs starting over from scratch

CWP : Software trigger / event reconstruction WG Issues

- Main challenges identified (II)
  - Data structure optimization
    - Improved I/O for analysis (also in light of event-processing facility discussions)
    - Use/Development of better lossless or lossy compression algorithms.
  - Online (or close to it) calibration and alignment
    - More sophisticated frameworks for monitoring
    - How to minimize the impact of calibration imperfections on ML driven anomaly detection and other novel algorithms
  - Code maintenance / sustainability challenges:
    - Lengthening timescales,
    - legacy codes at LHC
    - Opportunities provided by continuous integration infrastructures (e.g., for technical and physics regressions)
    - Link to training and career topics

CWP : Software trigger / event reconstruction WG next steps

- Expect to send outline of CWP chapter to WG next week
- Plan next WG meeting (vidyo) for end of April. Details to be discssed/announced
- Join us:
  - WG mailing list (google group)
  - Group mandate
  - Working document w/ links to agendas