GPU Enhancement of the Trigger to Extend Physics Reach at the LHC

(Poster #297)

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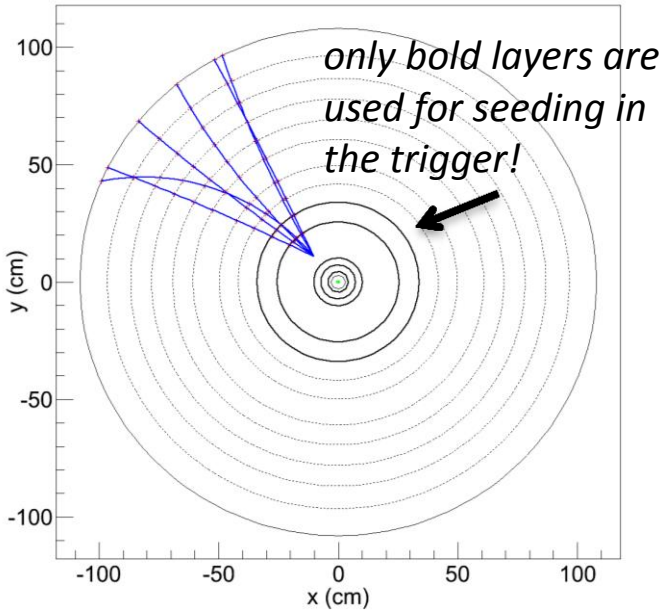
Motivation

In CMS (similarly in ATLAS), tracks are reconstructed regionally using the **Combinatorial Track Finder** (CTF):

- Candidate trajectories are created from triplet seeds.
- The trajectory is then propagated to other layers, where compatible hits are searched for and attached.

- As the pileup (and thus the number of hits) rises, the number of possible combinations increases significantly.
- Due to CPU limitations, highly displaced tracks are not reconstructed in the CMS high-level trigger.
- We have studied a new algorithm which reconstructs tracks holistically, thus reducing the effects of pileup and enabling us to look for these displaced tracks.



New Physics Reach

- Many models predict signatures with leptons and/or jets produced at a vertex significantly displaced from the primary vertex.
- A **very distinct** signal of potential new physics!
  - Hidden valley models with long-lived neutrals
  - Displaced black holes
  - Boosted jets
  - RPV SUSY models with long-lived χ^0
- See **arXiv:1308.6213** (sub. to JHEP) for more

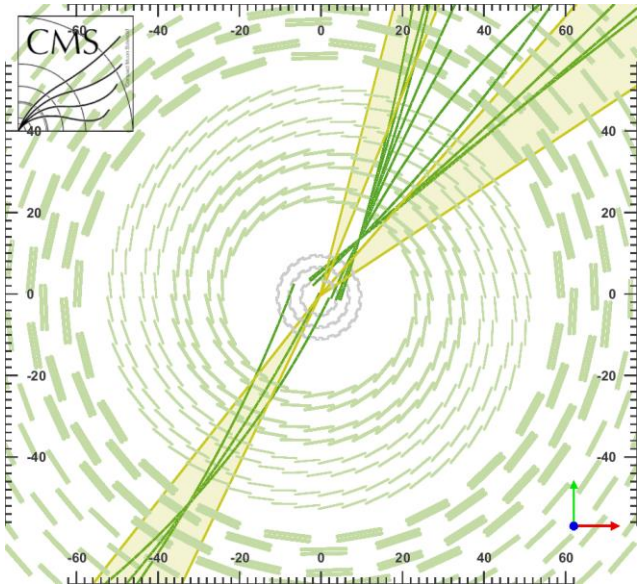
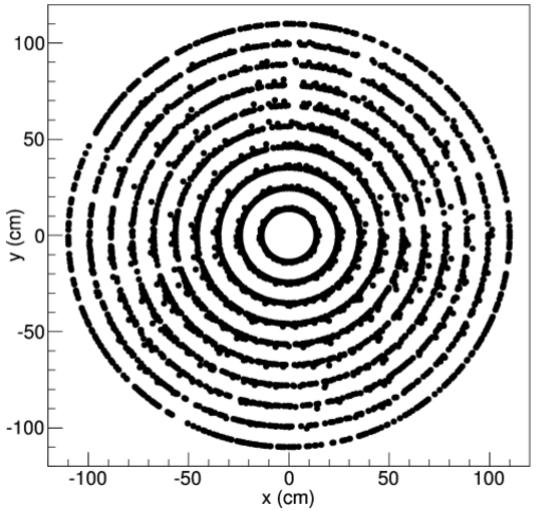


figure courtesy A. Zuranski

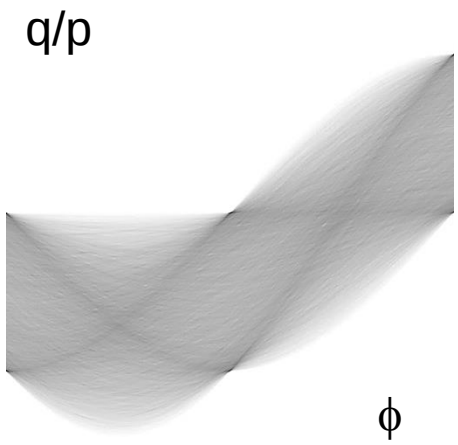
CMS simulation of a model with H → XX → 4 jets, where X is a long-lived neutral boson (CMS PAS EXO-12-038)

Hough Transform Algorithm

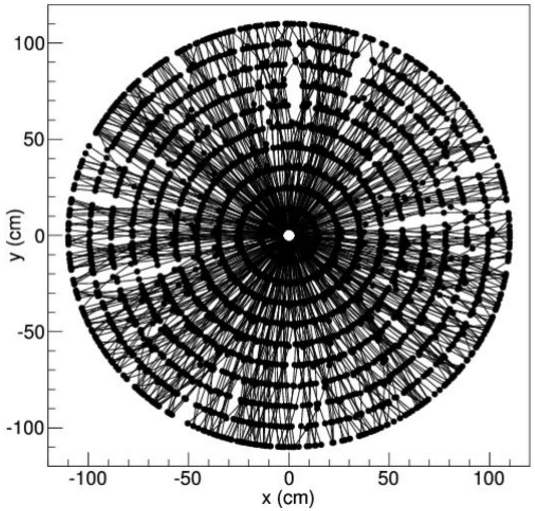
- Transforms **hits in space** to **lines in parameter space**; tracks are then the **maxima** in parameter space.
- Example with 500 curved tracks:



original simulated hits



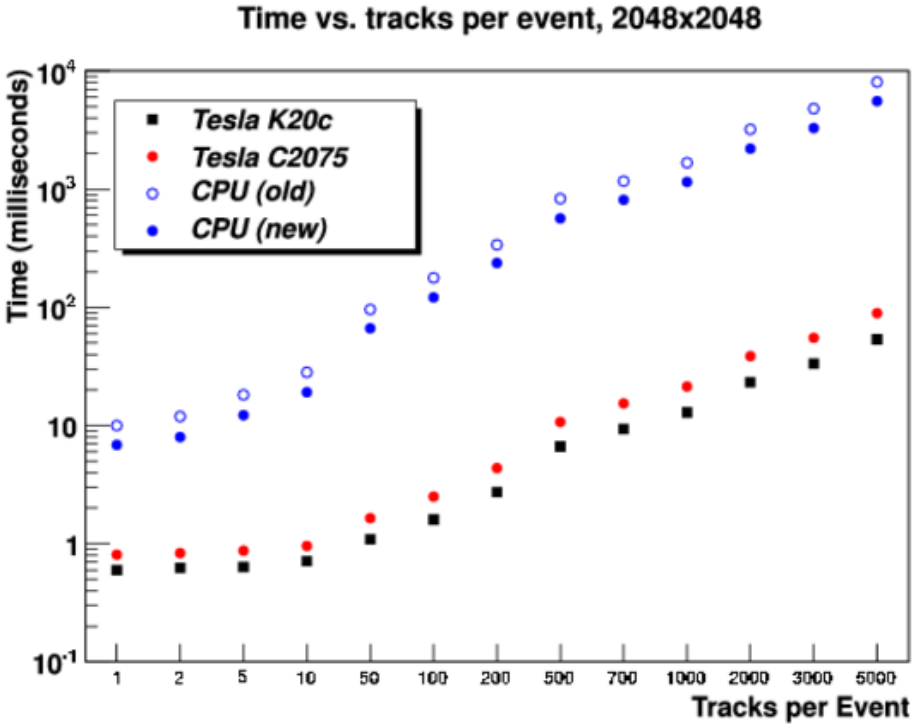
parameter space (curvature & angle) after Hough transform



final reconstructed tracks (efficiency & purity both approx. 85%)

GPU Implementation

- Hough transform is a **natural candidate** for GPU acceleration using general-purpose GPU programming with CUDA.



See **arXiv:1309.6275** for more on these implementations

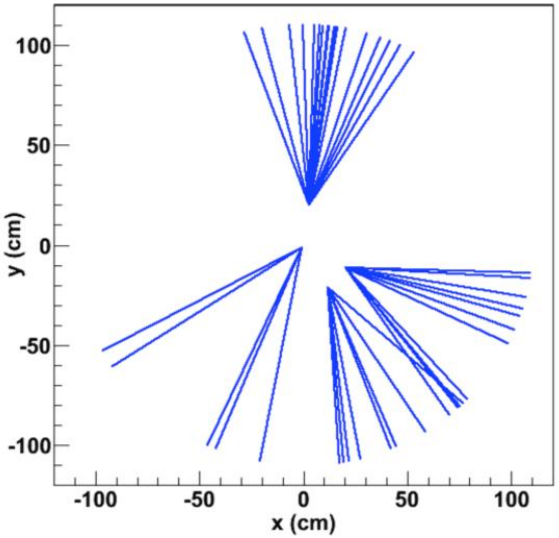
CPU implementation before (open) and after (filled) optimization (performed on Intel Core i7-3770)

GPU implementation on Tesla C2075 (red) and K20c (black) *–10-60x faster!*

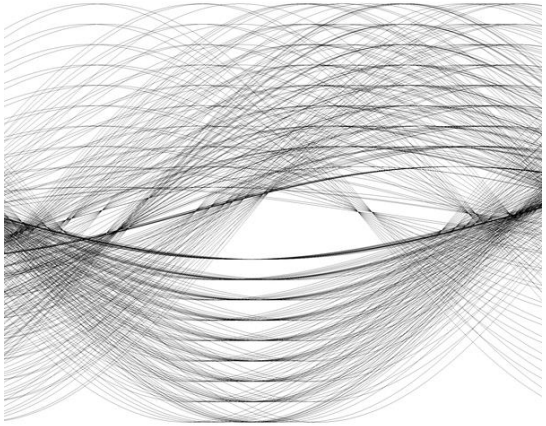
- Also a candidate for investigating with Xeon Phi

Displaced Vertices

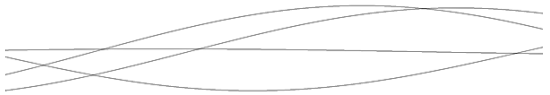
- Vertices are also a valuable tool for finding displaced jets & black holes.
- After applying Hough transform once, *apply it again* to find intersections of tracks (i.e., vertices):



original simulated tracks (4 displaced jets)



parameter space after first Hough transform



after 2nd Hough transform, the four vertices are now visible!

Conclusions

- The Hough transform in conjunction with GPU computing is a **very interesting** alternative to the existing CTF:
  - We can reconstruct all tracks **in a single step**, helping to reduce the effects of increasing pileup.
  - We can **extend the physics reach of the trigger** by making it possible to search for models not practical with the current trigger.
- Currently working on building a more realistic detector model which could be integrated into the CMS framework.
- See our paper: ***JINST* 8 P1005 (2013)**
- **Thanks for your votes!**