JÜLICH
FORSCHUNGSZENTRUM

panda

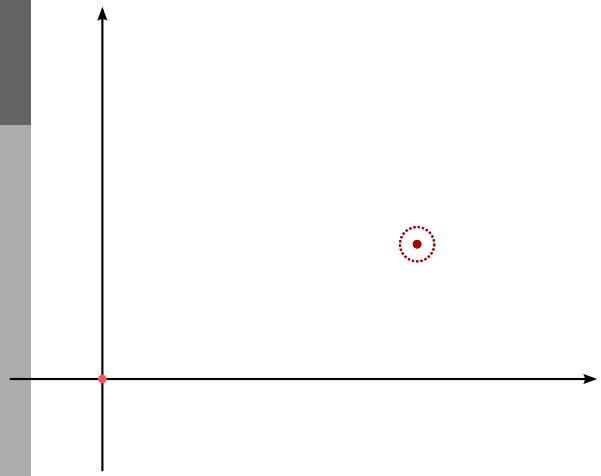
Update on Online Tracking Algorithms with GPUs

PANDA CM 52, Gießen | Pattern Recognition Session

2015-03-16 | **Ludovico Bianchi** *(Forschungszentrum Jülich)*

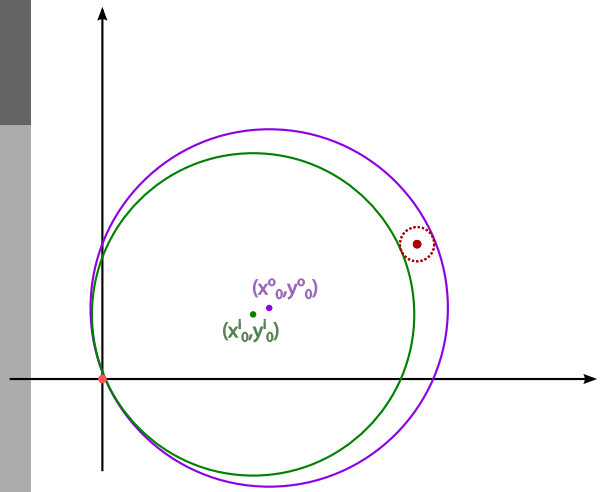
Circle Hough — Algorithm

- Hits from central tracking detectors (MVD, STT, GEM)
- For each hit: sampling Hough parameter space
  - Define family of circles in the (x, y) plane, passing through IP, tangent to drift isochrone at hit point $(x_{\text{hit}}, y_{\text{hit}})$
- For each collection of hits:
  - Measure frequency of Hough values
  - Most frequent Hough values $\Longleftrightarrow$ tracks in the coordinate space



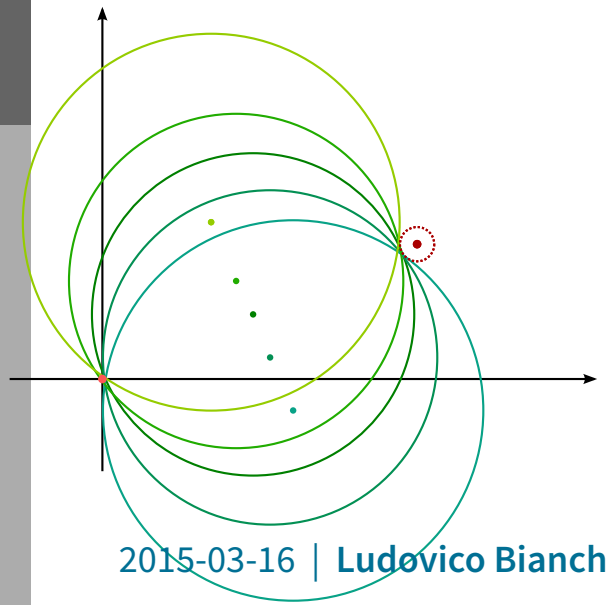
Circle Hough — Algorithm

- Hits from central tracking detectors (MVD, STT, GEM)
- For each hit: sampling Hough parameter space
  - Define family of circles in the (x, y) plane, passing through IP, tangent to drift isochrone at hit point $(x_{\text{hit}}, y_{\text{hit}})$
- For each collection of hits:
  - Measure frequency of Hough values
  - Most frequent Hough values $\Longleftrightarrow$ tracks in the coordinate space



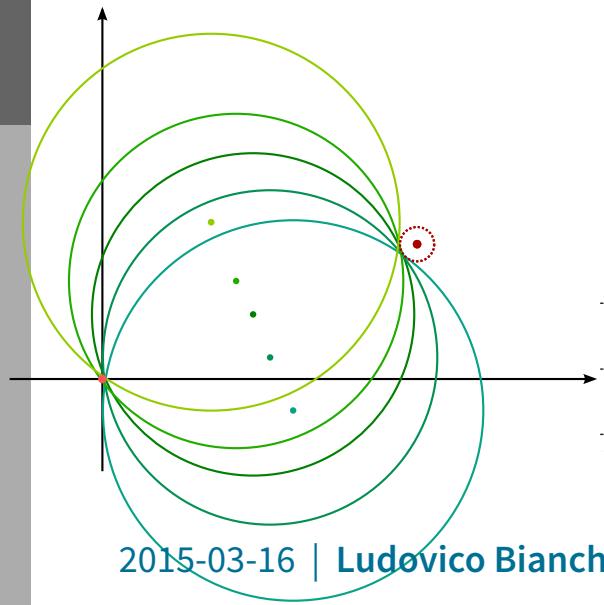
Circle Hough — Algorithm

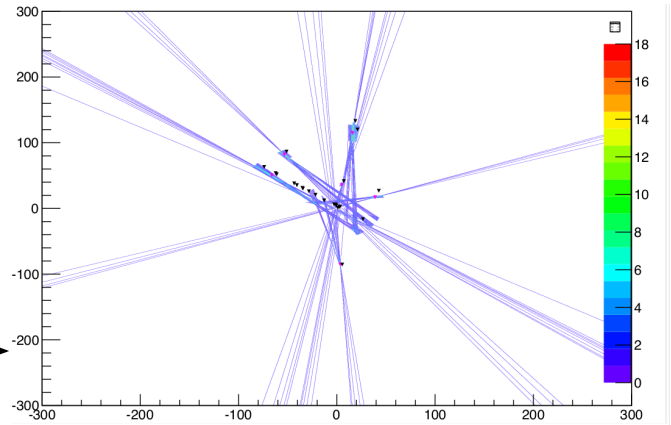
- Hits from central tracking detectors (MVD, STT, GEM)
- For each hit: sampling Hough parameter space
  - Define family of circles in the (x, y) plane, passing through IP, tangent to drift isochrone at hit point $(x_{\text{hit}}, y_{\text{hit}})$
- For each collection of hits:
  - Measure frequency of Hough values
  - Most frequent Hough values $\Longleftrightarrow$ tracks in the coordinate space



Circle Hough — Algorithm

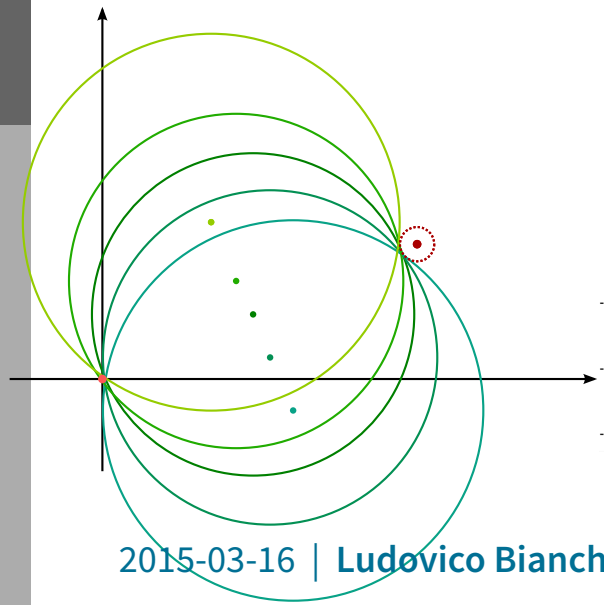
- Hits from central tracking detectors (MVD, STT, GEM)
- For each hit: sampling Hough parameter space
  - Define family of circles in the (x, y) plane, passing through IP, tangent to drift isochrone at hit point $(x_{\text{hit}}, y_{\text{hit}})$
- For each collection of hits:
  - Measure frequency of Hough values
  - Most frequent Hough values $\Longleftrightarrow$ tracks in the coordinate space

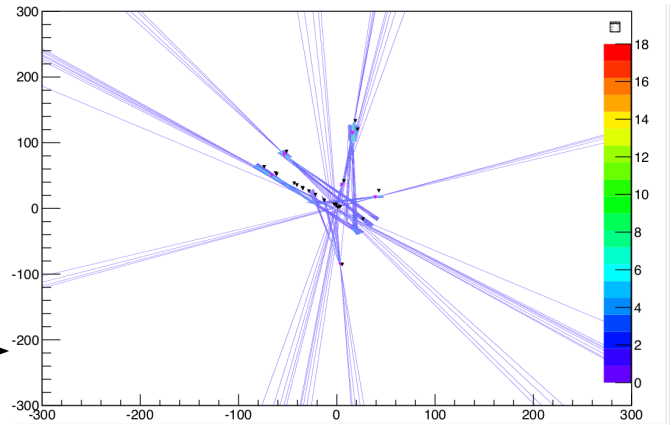


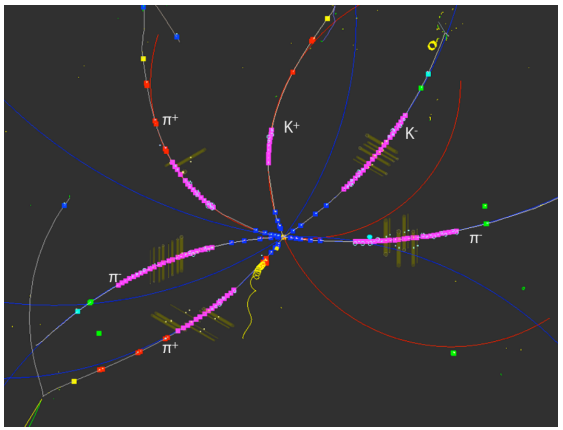


Circle Hough — Algorithm

- Hits from central tracking detectors (MVD, STT, GEM)
- For each hit: sampling Hough parameter space
  - Define family of circles in the (x, y) plane, passing through IP, tangent to drift isochrone at hit point $(x_{\text{hit}}, y_{\text{hit}})$
- For each collection of hits:
  - Measure frequency of Hough values
  - Most frequent Hough values $\Longleftrightarrow$ tracks in the coordinate space







Circle Hough — On GPUs

- Computational tasks
  1. Generate angles
  2. Generate Hough circles
  3. Collect circle parameters in histogram
  4. Find peaks in distribution
- Previously:
  - (1), (2) on GPU $\longrightarrow$ (3), (4) on CPU
  - Level of parallelism: angles
  - PandaRoot integration
  - Performance tests: comparison CPU/GPU, total execution time

  ☞ A. Herten's presentation at CM 51
- **Current status**:
  - \+ Levels of parallelism: hits, angles
  - \+ Performance tests: in-depth GPU profiler analysis using `nvprof`

GPUs

Graphics processing units

- Accelerators originally created for graphics
- High performance/efficiency for data-parallel computation
- Kernels (function) run on device, launched from host (CPU)
- High internal memory bandwidth (∼250 GB/s)
- Memory transfers to/from host limited by interface
- Two main categories
  - HPC: designed for computation,
    higher build quality and per-unit specs
  - Consumer: designed for graphics, cheaper (10–30x), more GFLOPS/€

Performance Tests

- Study GPU Circle Hough algorithm as a function of # of processed hits
- Performance analysis using `nvprof`
  - Access to internal metrics allows targeted optimization
- Main processes:
  - *Kernel*: Circle calculation
  - *Memcpy*: Copy circle parameters from device to host
- Negligible contributions: Angle generation, copy hit data HtD
- Angle sampling granularity: 1 degree

Devices Under Test

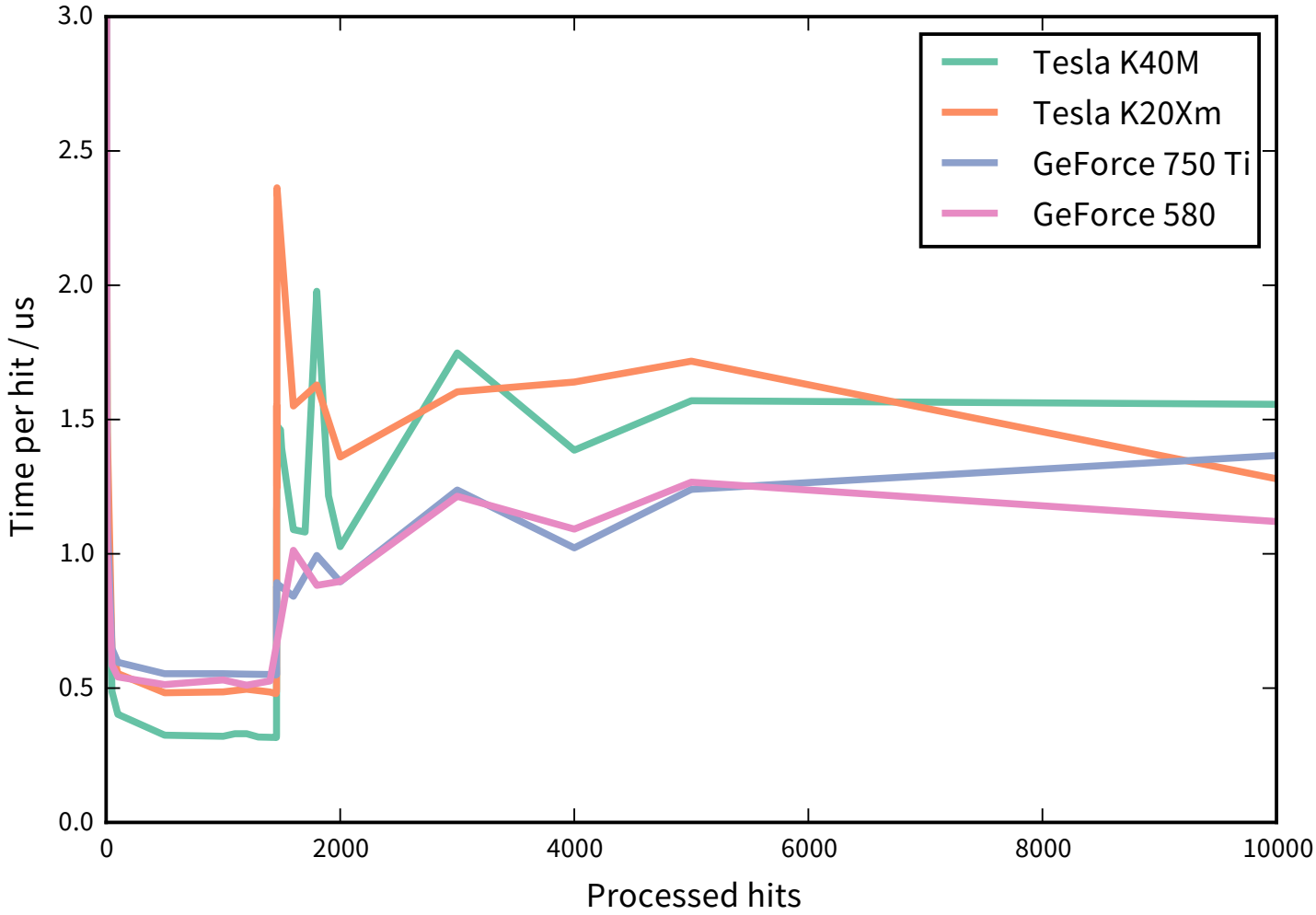
Some specifications

Property	Unit	Device			
		GeForce		Tesla	
		GTX 580	GTX 750 Ti	K20X	K40
Manufacturer		NVIDIA			
Release Year		2010	2014	2012	2013
Chipset		Fermi	Maxwell	Kepler	
Multiprocessors	#	16	5	14	15
CUDA **Cores**	#	512	640	2688	2880
GPU Clock	MHz	1544	1110	732	745
Global Memory	GB	1.5	2	6	12
Memory Clock	MHz	2004	2700	2600	3004
Peak Performance	GFLOPS	1580	1306	3950	4290
Price	Euro	190	150	3600	3800

Table: A. Herten

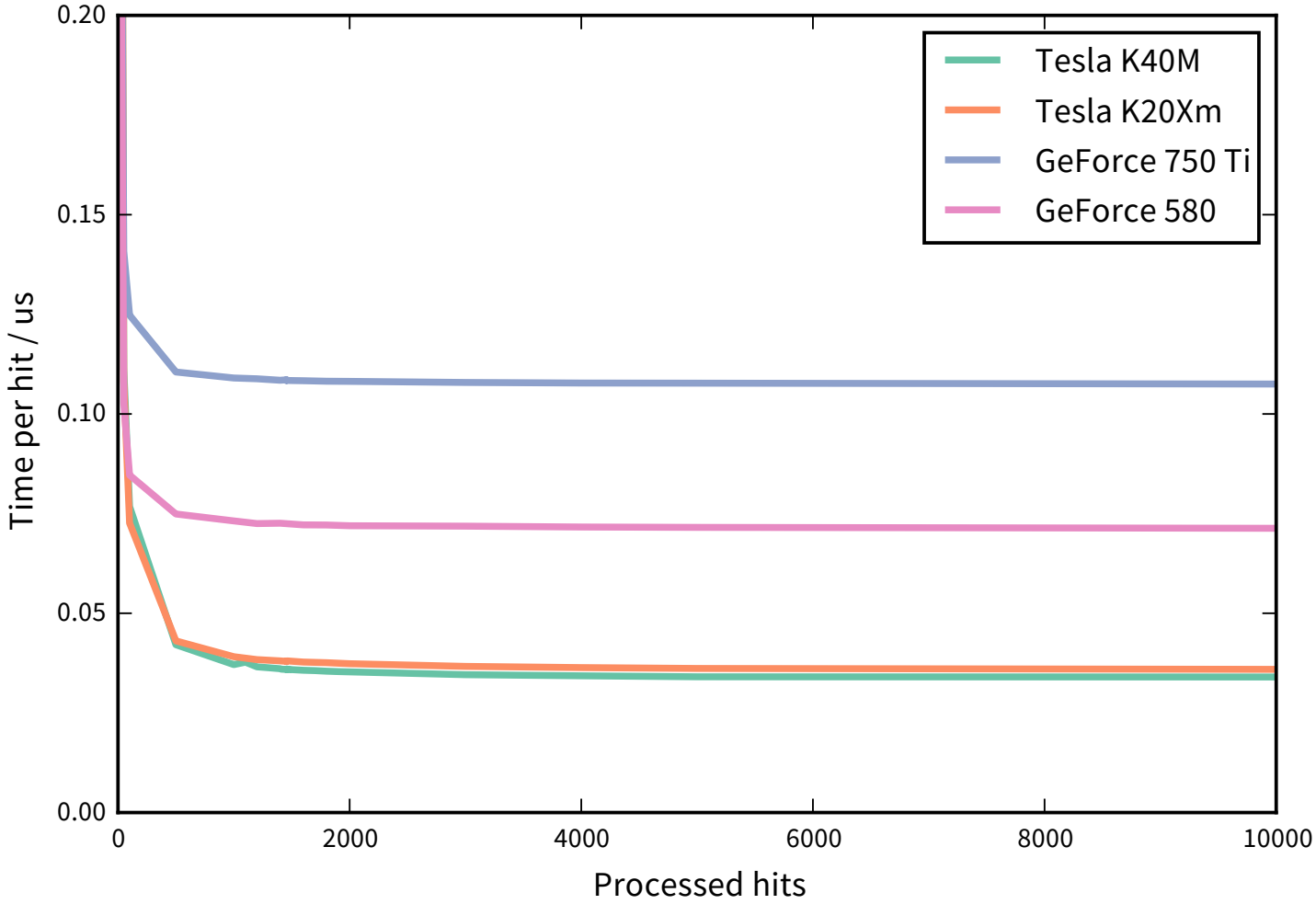
Performance Tests

Total time per hit



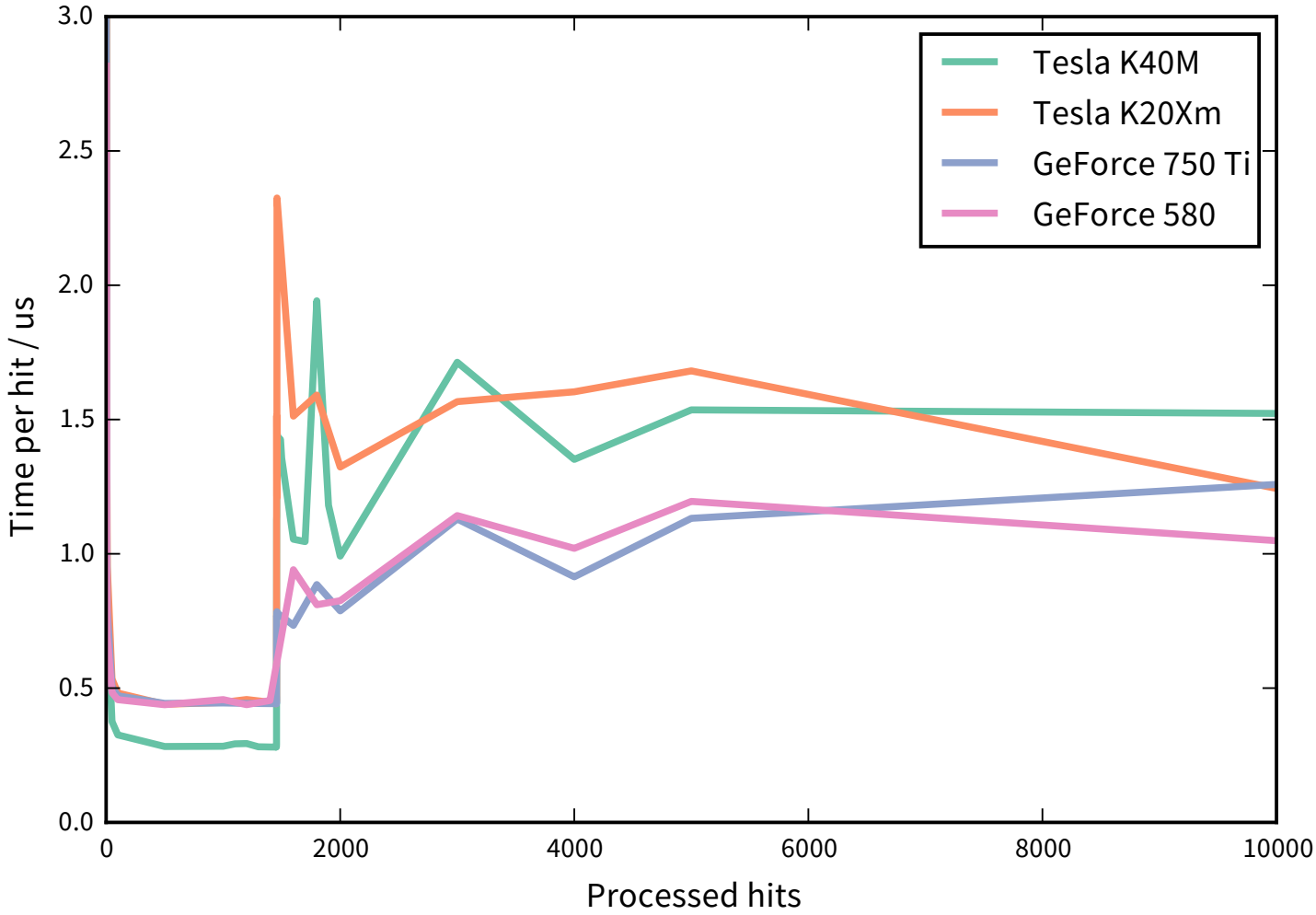
Performance Tests

Kernel time per hit



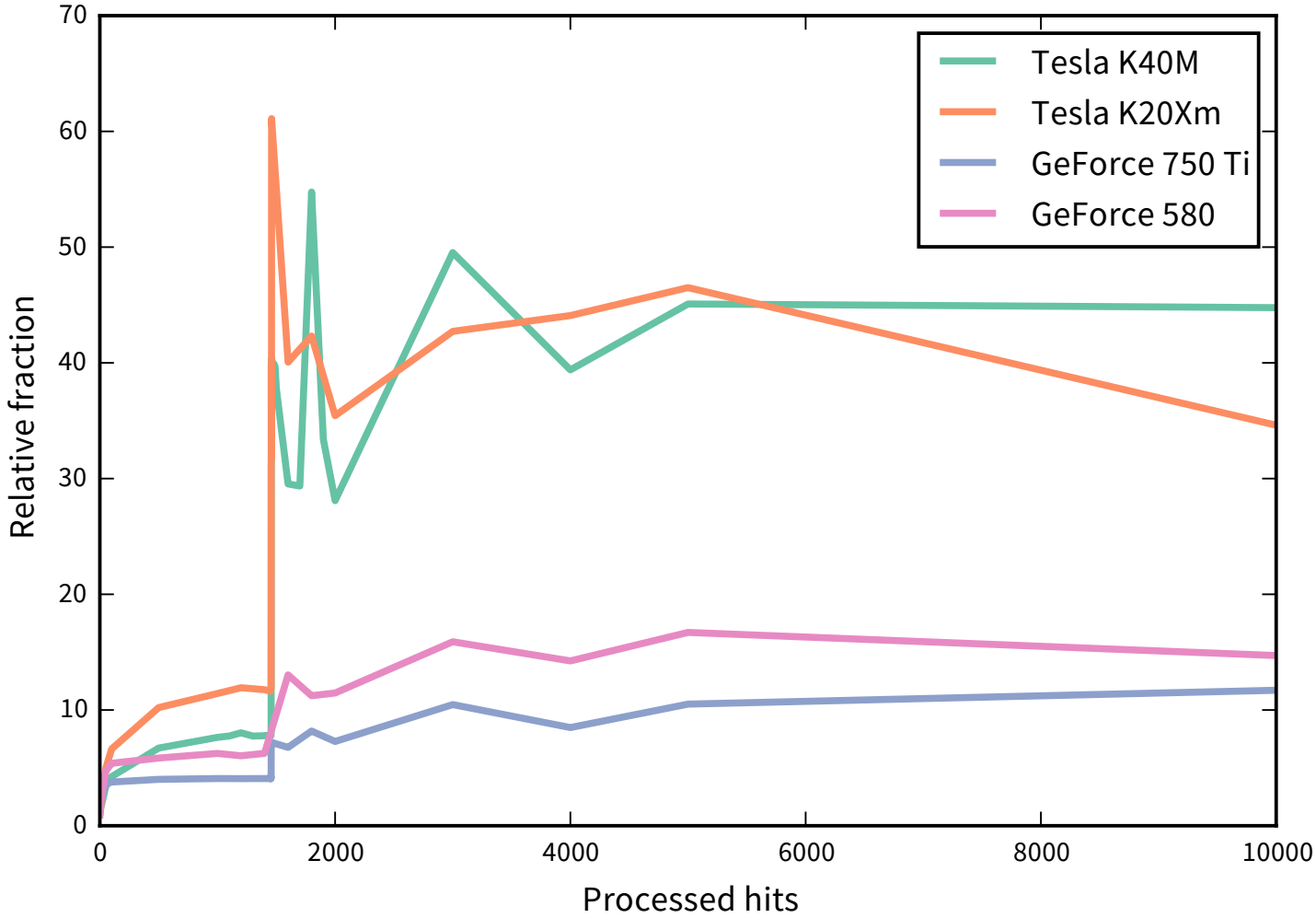
Performance Tests

Memcpy time per hit



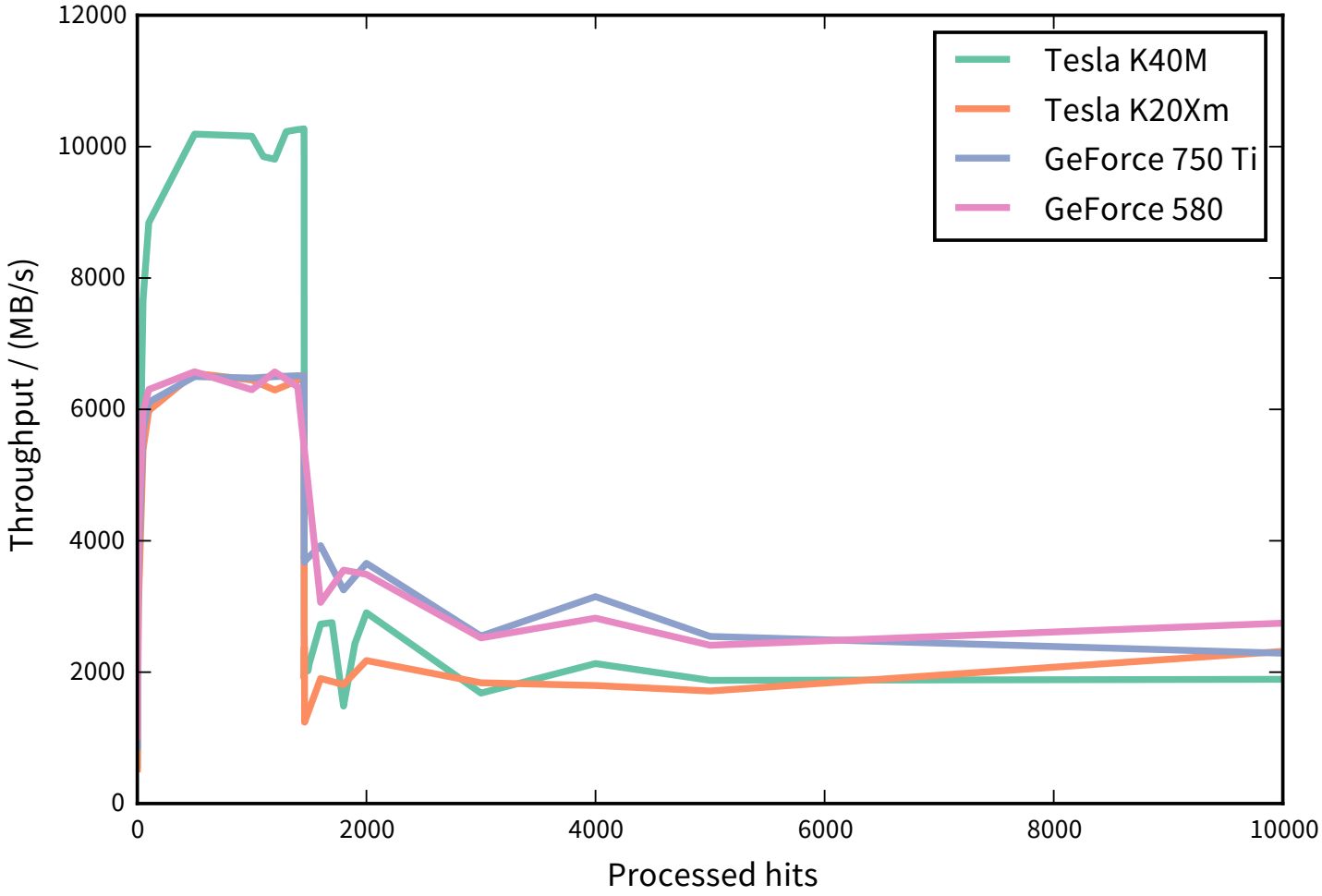
Performance Tests

Memcpy/kernel time ratio



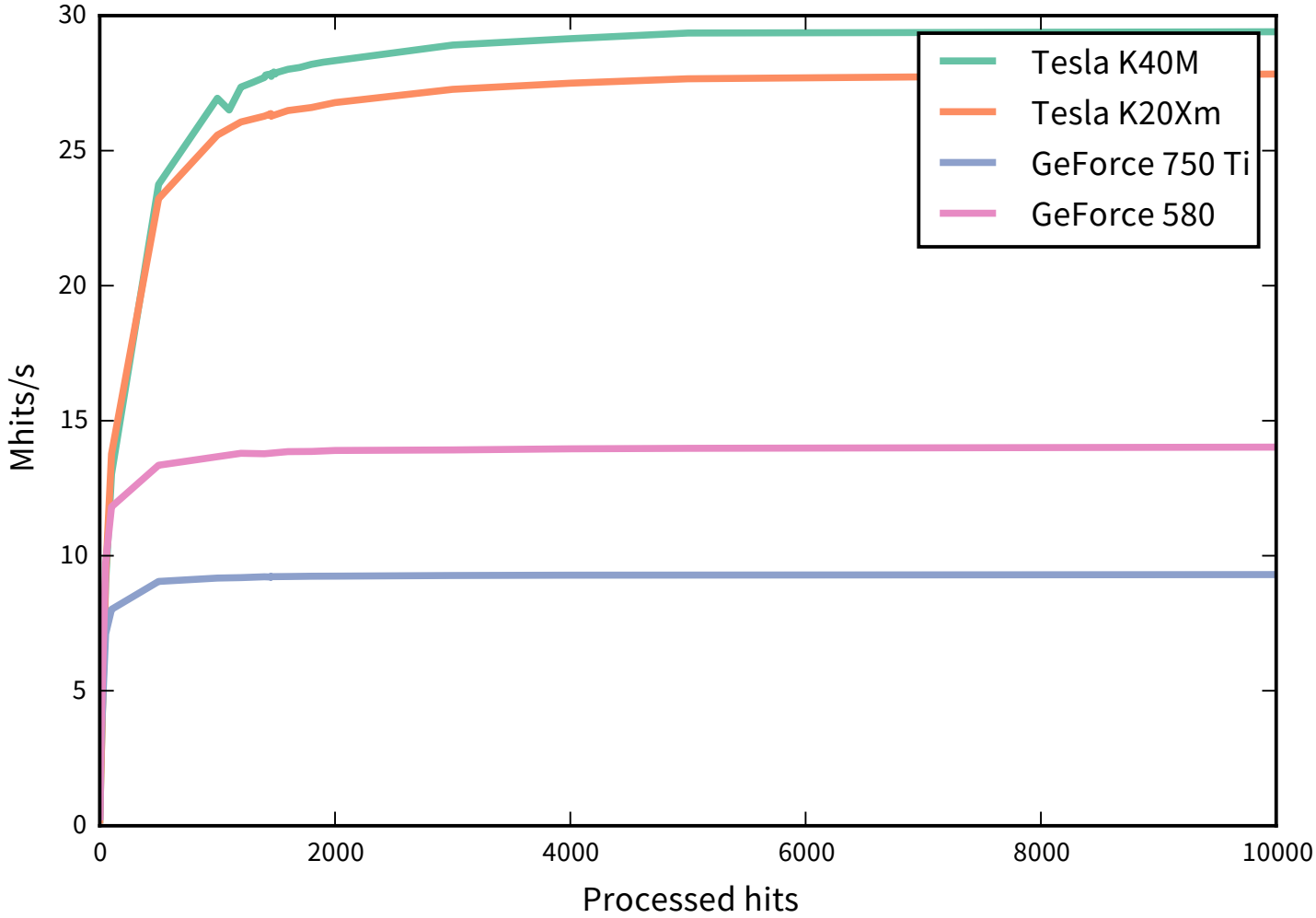
Performance Tests

Memcpy throughput



Performance Tests

Kernel-only performance



Conclusions

JÜLICH FORSCHUNGSZENTRUM

p̄anda

Summary

- Circle Hough: bulk parallelism with angles, hits
- Profiling with `nvprof` for GPU-specific optimization
- Limiting factor is memory copy to host memory circle parameters to CPU for histogramming and peakfinding
- Optimal values depend on both physics and hardware

Outlook

- Histogramming on GPU
- OpenACC: pragma-based accelerator programming paradigm

The End

Thanks for your attention!

Image credit: deviantart.com

l.bianchi@fz-juelich.de