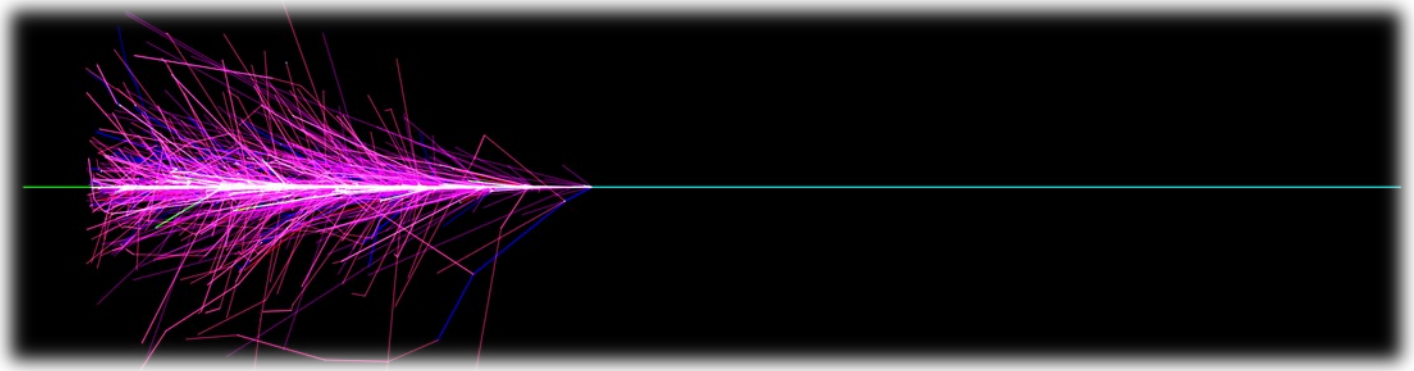
technische universität dortmund

SFB 876 Providing Information by Resource-Constrained Data Analysis

lehrstuhl physik e5



GPU based photon propagation for CORSIKA 8

Dominik Baack

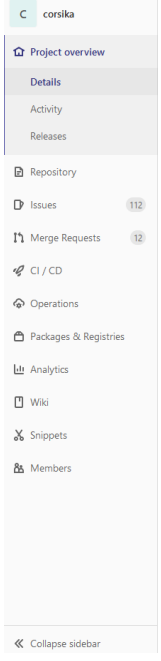
5th ICPPA

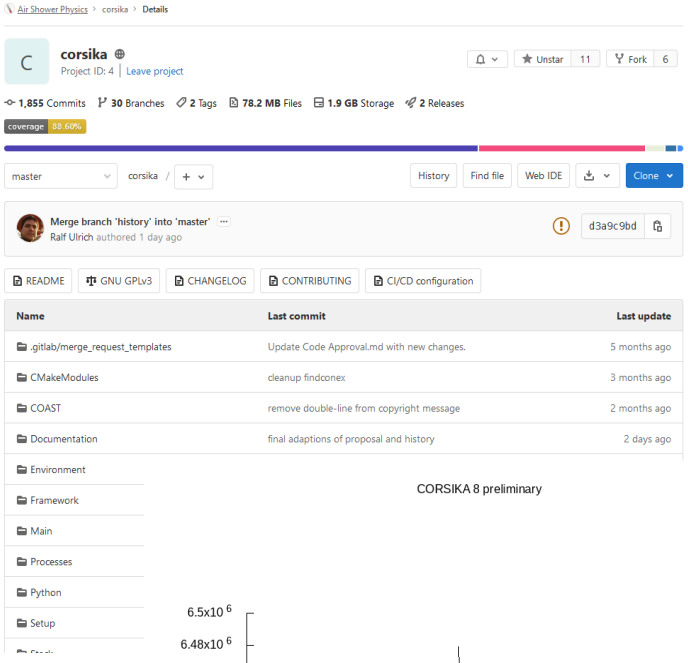
Online

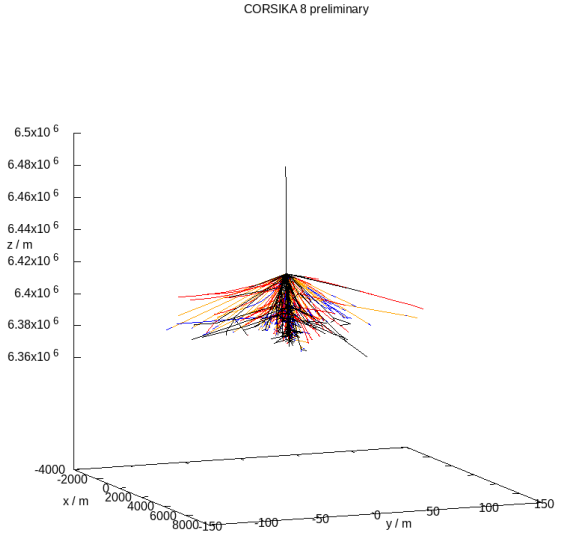
09. 10. 2020

Corsika 8 Framework

- Successor of the well known Corsika 7 simulation
- Core completely written in C++
- https://gitlab.ikp.kit.edu/AirShowerPhysics/corsika







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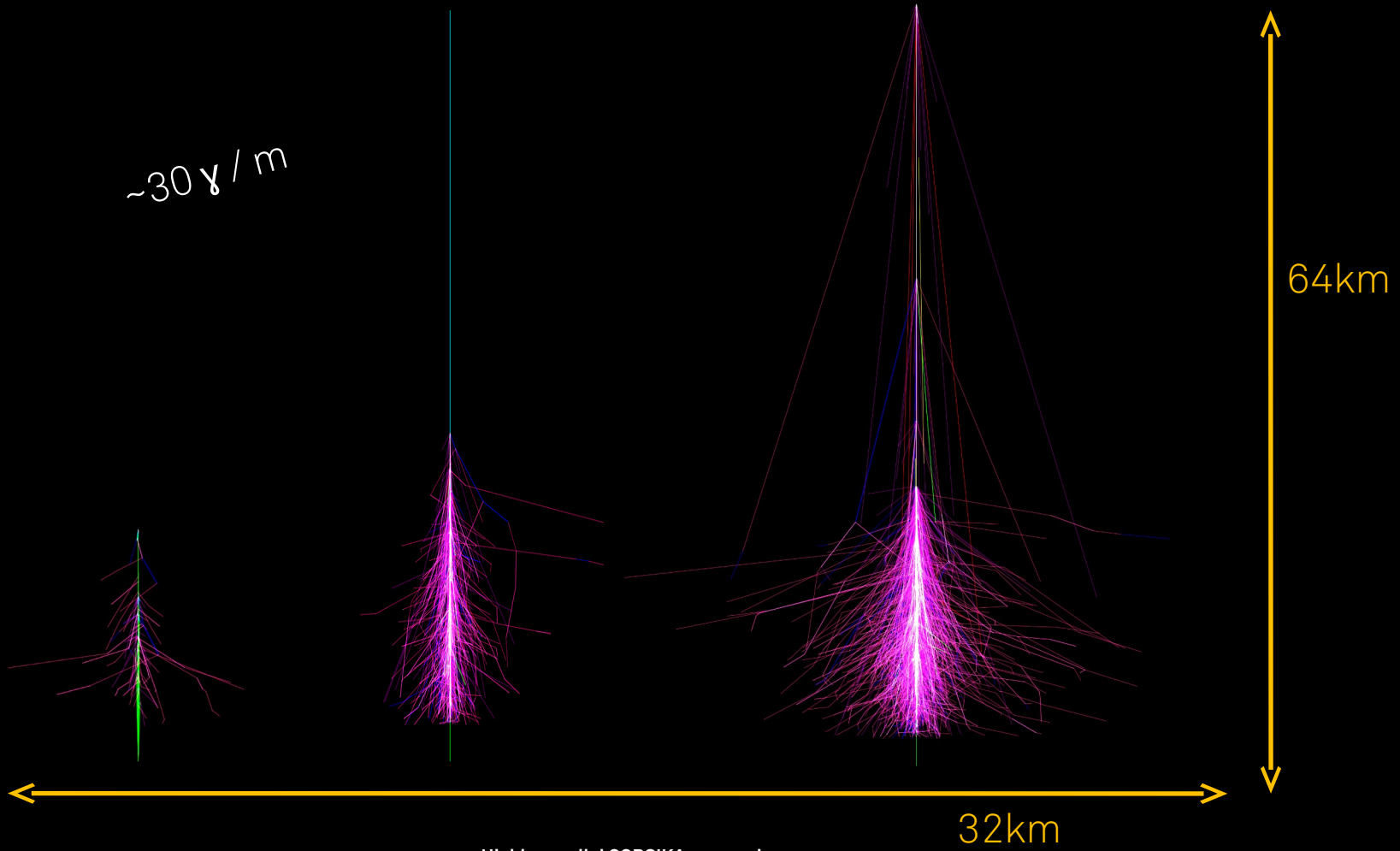

Highly parallel CORSIKA processing

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Function	CPU Time: Total ▼	CPU Time: Self	Instructions Retired: Total
aamain	2232.101s	0.020s	100.0%
__libc_start_main	2232.101s	0s	100.0%
main	2232.101s	0s	100.0%
_start	2232.101s	0s	100.0%
box3	2208.159s	0.020s	99.0%
cerenk	2078.871s	533.937s	93.8%
egs4	2026.466s	0s	90.8%
em	2026.466s	0s	90.8%
shower	2026.466s	0.070s	90.8%
electr	2023.865s	34.329s	90.7%
distip	449.052s	203.941s	16.8%
__ieee754_acos_sse2	358.305s	318.770s	21.0%
tofip	336.495s	214.020s	15.5%
rmmard	250.622s		
__cos_avx	192.107s		
rhof	190.668s		
updatc	187.214s		
__GI___exp	180.922s		
update	180.016s		
__ieee754_exp_avx	166.768s		
mutrac	165.054s		
do_sincos_1	110.374s		
__sin_avx	104.359s		
telout_	55.212s		
do_sincos_1	47.284s		
__doasin	37.784s		
do_cos	32.290s		

Callees	CPU Time: Total ▼	CPU Time: Self
▼ cerenk	2078.871s	533.937s
▶ distip	449.052s	203.941s
▶ tofip	336.495s	214.020s
▶ rmmard	231.852s	231.438s
▶ rhof	190.258s	20.957s
▶ __cos_avx	179.945s	38.086s
▶ __sin_avx	95.118s	25.432s
▶ telout_	55.212s	54.892s
▶ __tan_avx	2.140s	1.960s
▶ thick	1.880s	0.290s
▶ __ieee754_log_av	1.280s	1.280s

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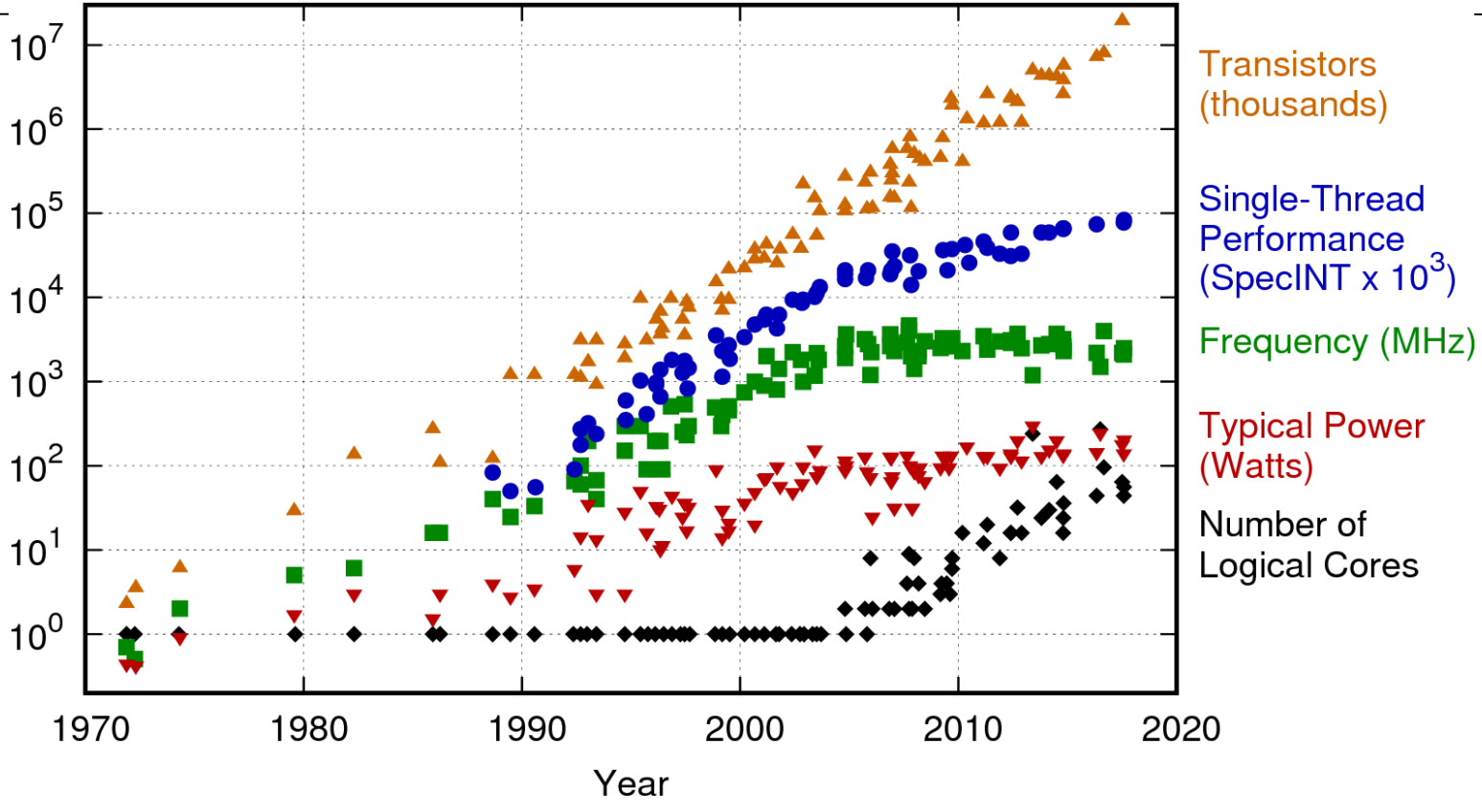
Corsika 7

42 Years of Microprocessor Trend Data



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp

https://www.karlrupp.net/2018/02/42-years-of-microprocessor-trend-data/

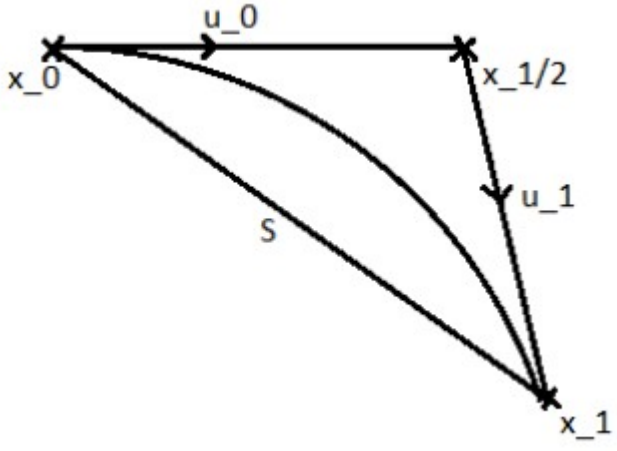
High parallel Cherenkov light

- Completely independent calculations for each photon
- “Simple” arithmetic no complex processes
- OpenCL allows platform independent vectorization & parallelization, first test shows good performance

  … but …
- CUDA – Nvidia proprietary but higher performance possible

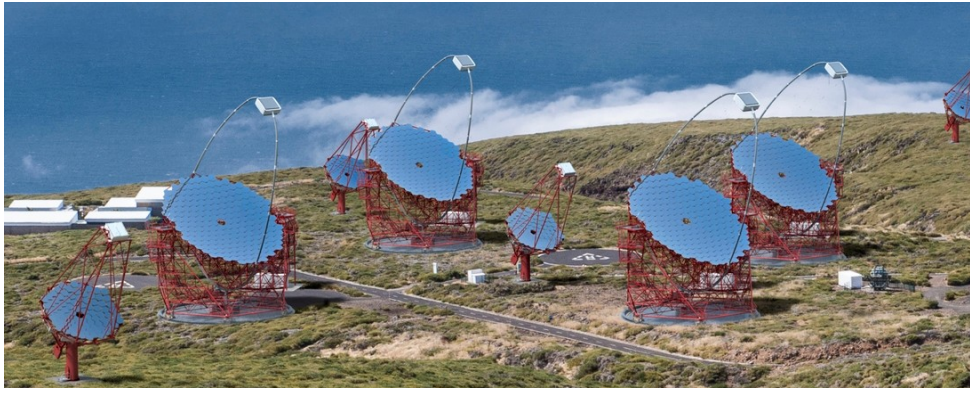
Prerequisite

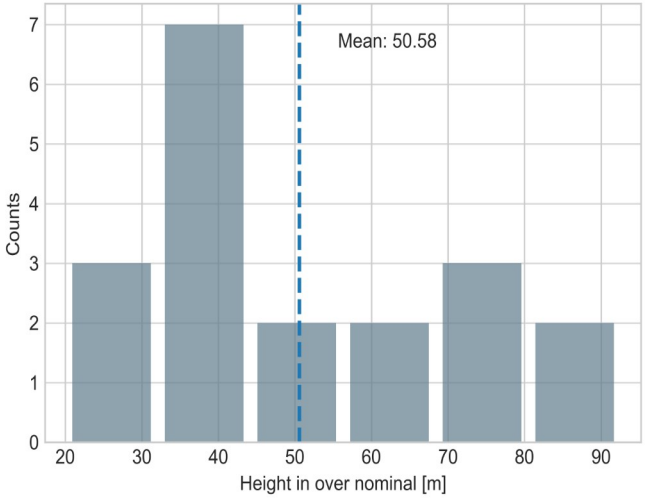
- Linear particle tracks
- >>1024 track segments accumulated to reach good performance

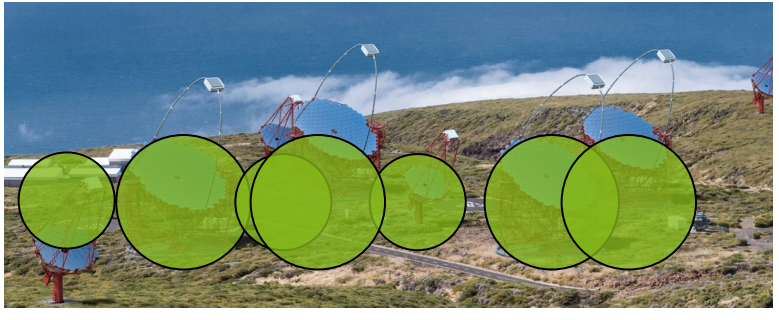


Andre Schmidt - KIT

Geometry

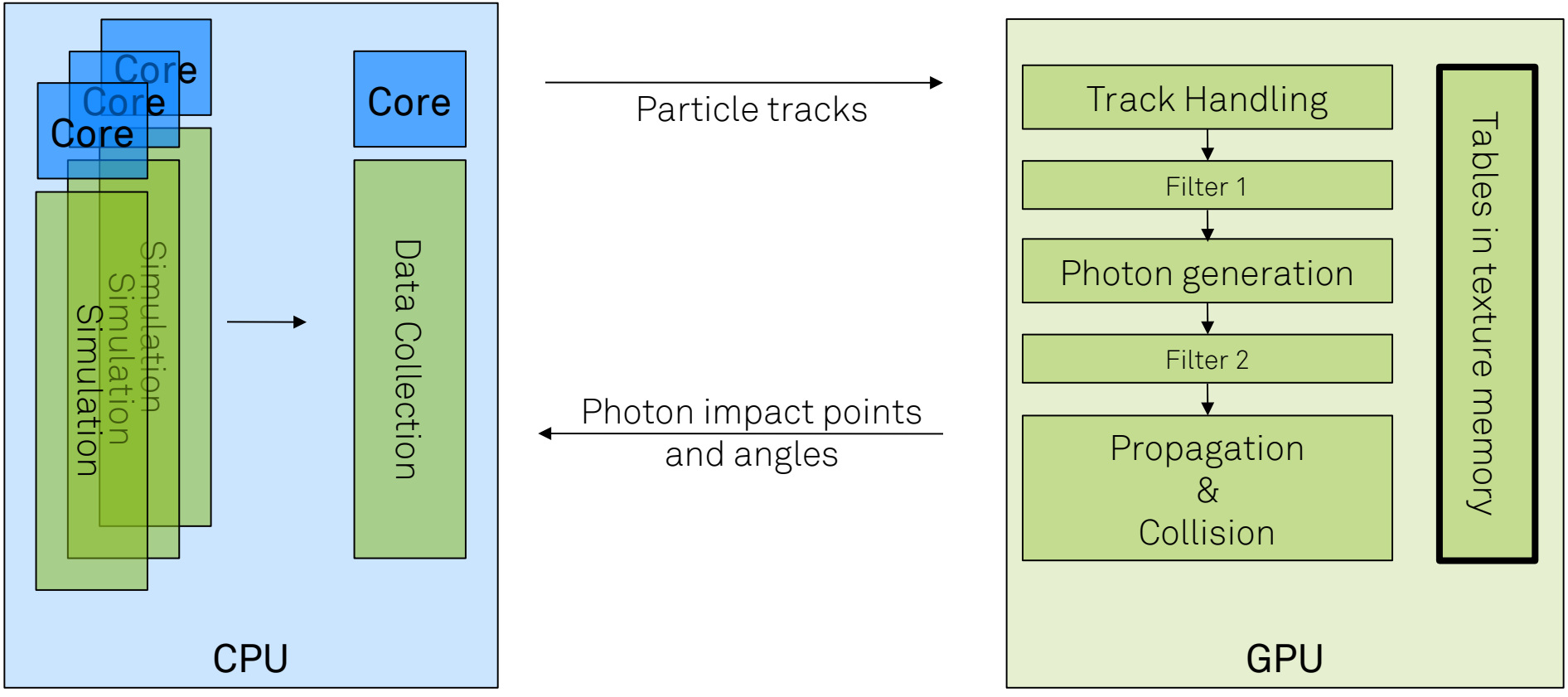




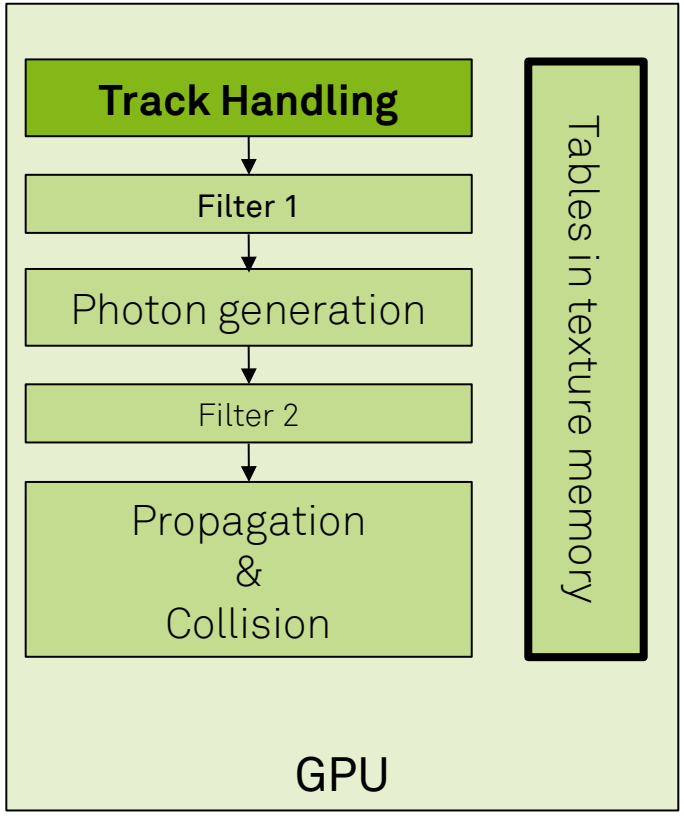


CTA Observatory - https://www.cta-observatory.org/about/how-cta-works/optimized-cta_orm_comp_webupdated_1800x590/

Computing Structure



Computing Structure

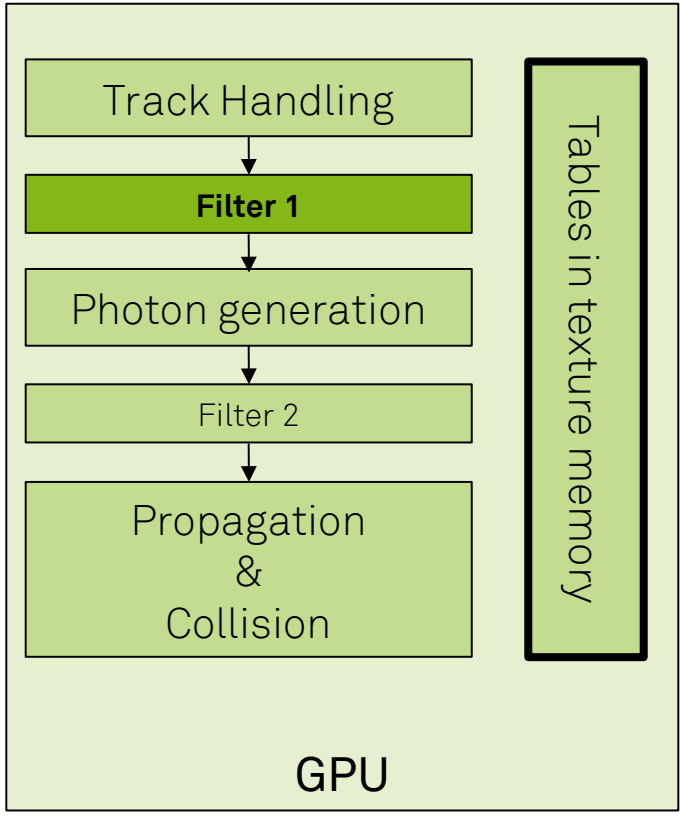


- All Tracks to GPU
  - More work to GPU
  - Less data transfer
-
- Load, convert and distribute tracks to warps
- Split tracks if necessary partial

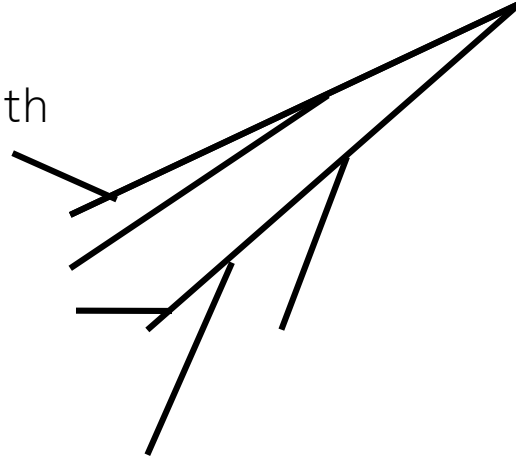
$$\beta_{start} < 1 < \beta_{end}$$
$$\beta_{end} < 1 < \beta_{start}$$

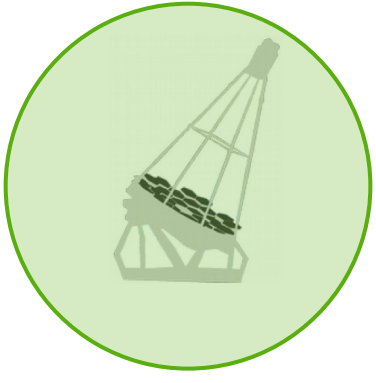
- Remove any tracks with $\beta < 1$

Computing Structure

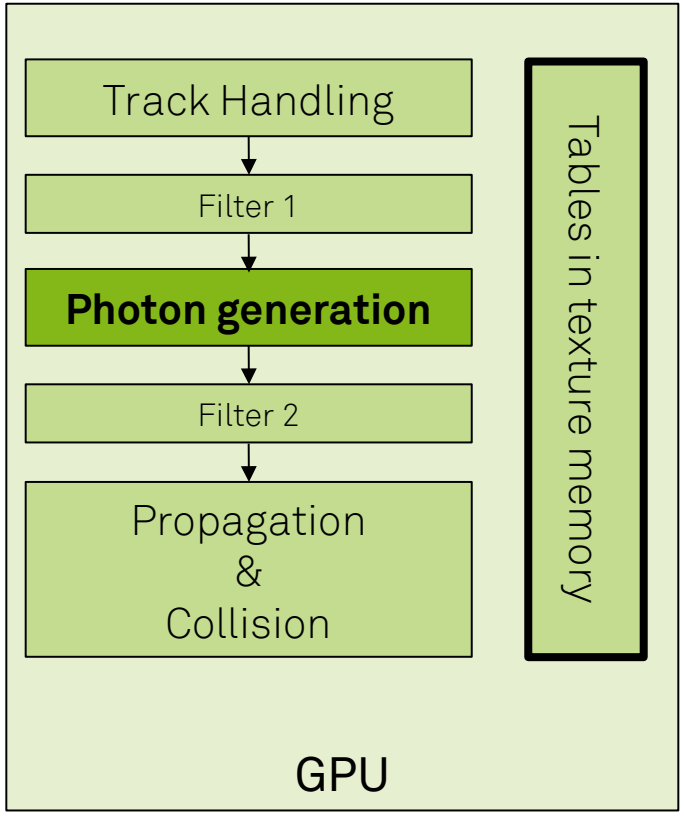


- Remove particle $\vec{v} \cdot \vec{p} \leqslant \text{cut}$
- Angular cut not possible with
  - diffuse Emission
  - Fluorescence





Computing Structure

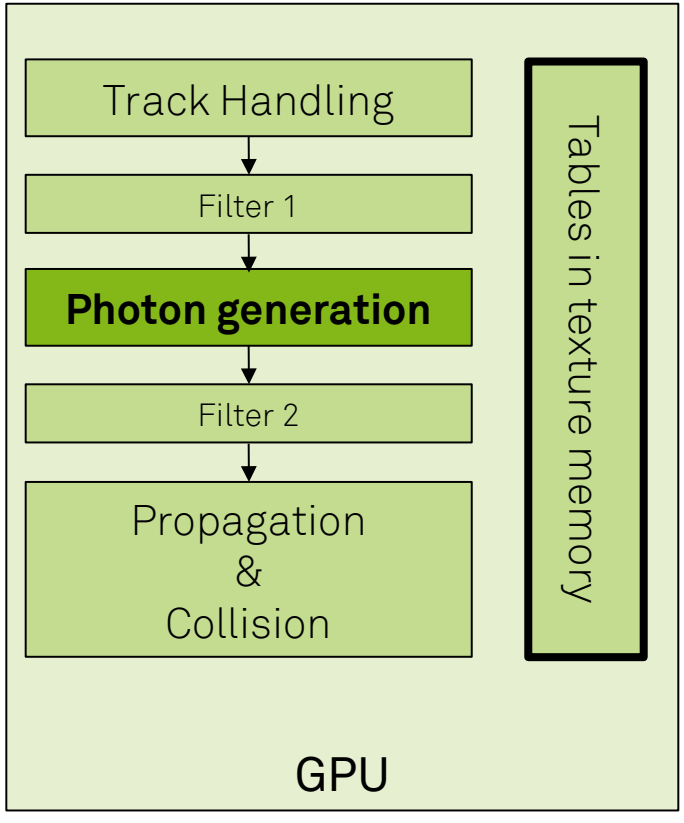


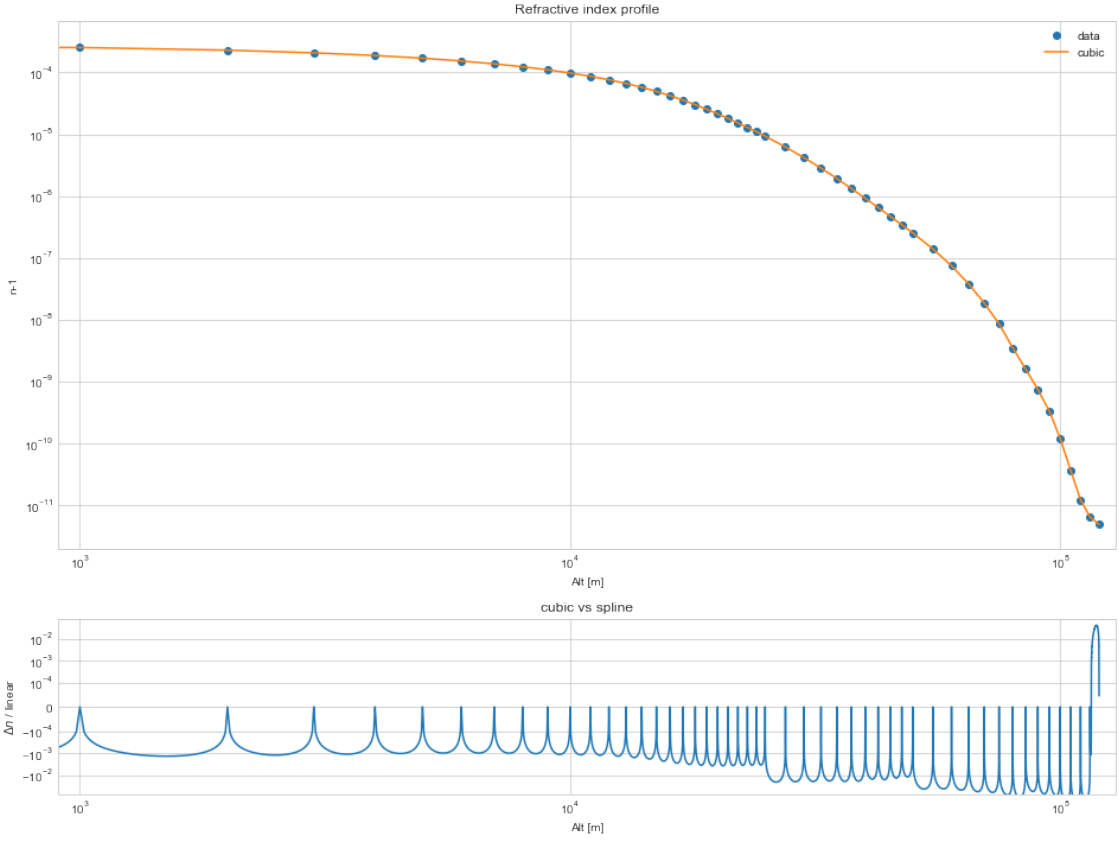
- Use presolved Frank-Tamm Formula

$$\frac{d^2N}{dxd\lambda} = \frac{2\pi\alpha z^2}{\lambda^2} \cdot sin^2(\theta_c)$$

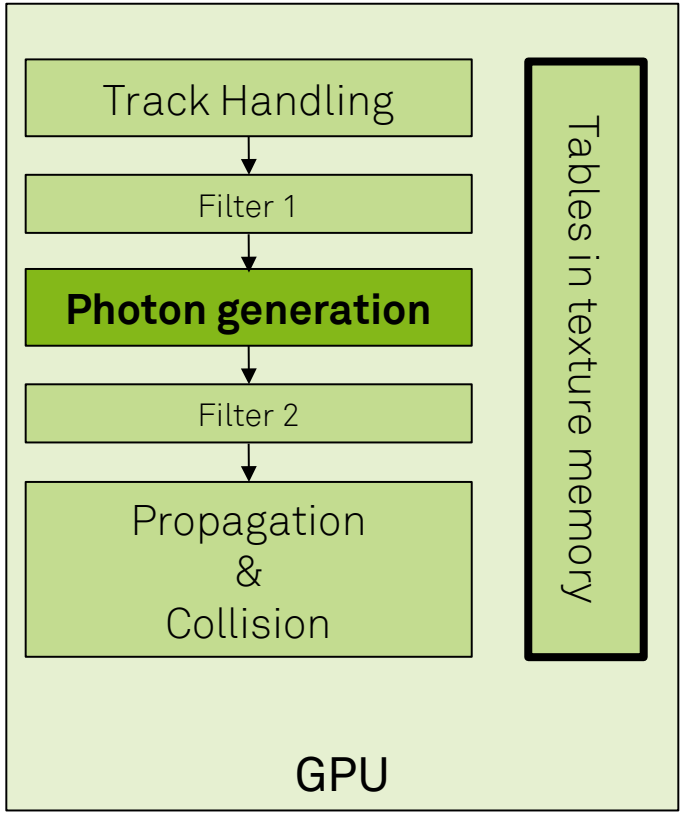
to calculate N and α

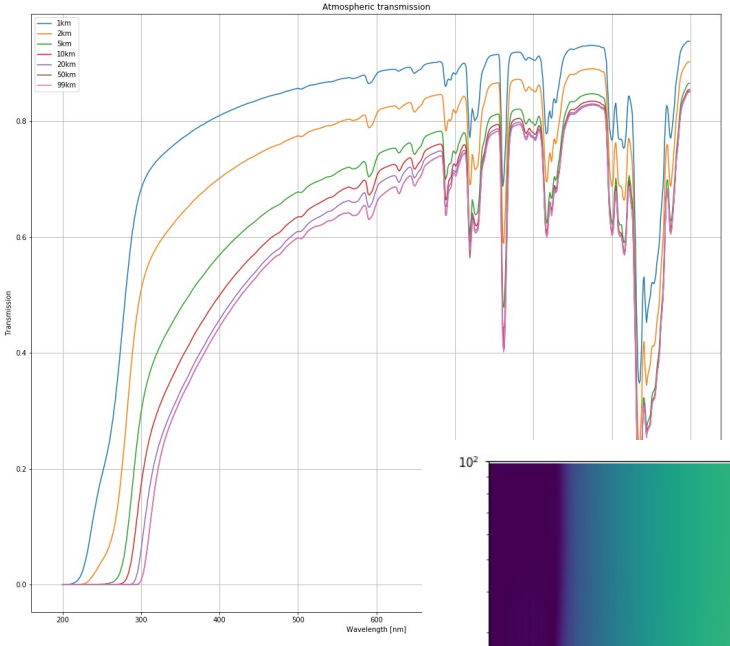
Computing Structure

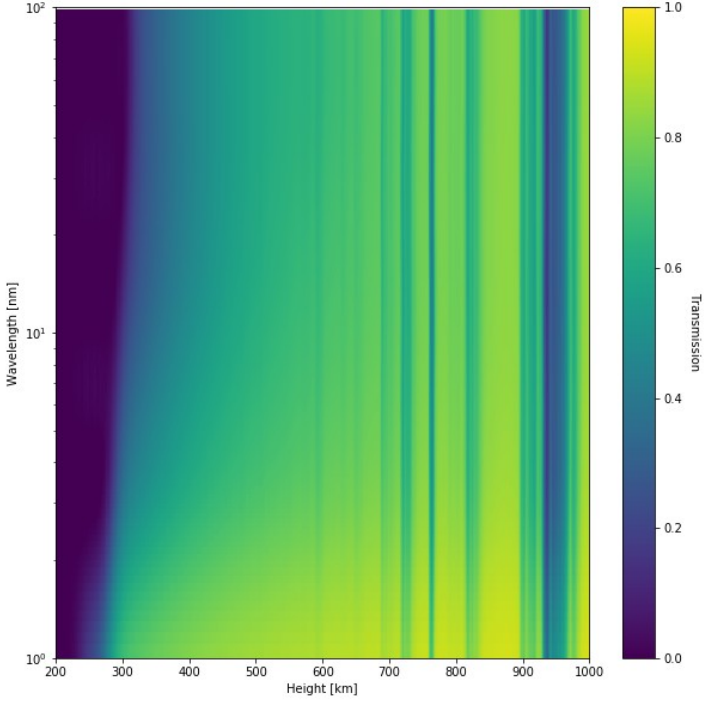




Computing Structure







GPU based photon propagation for CORSIKA 8

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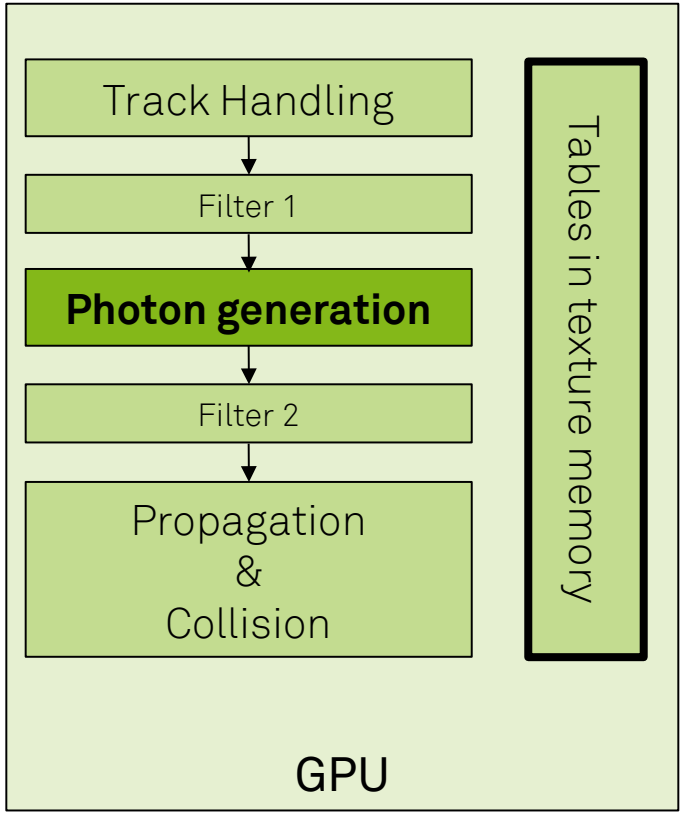
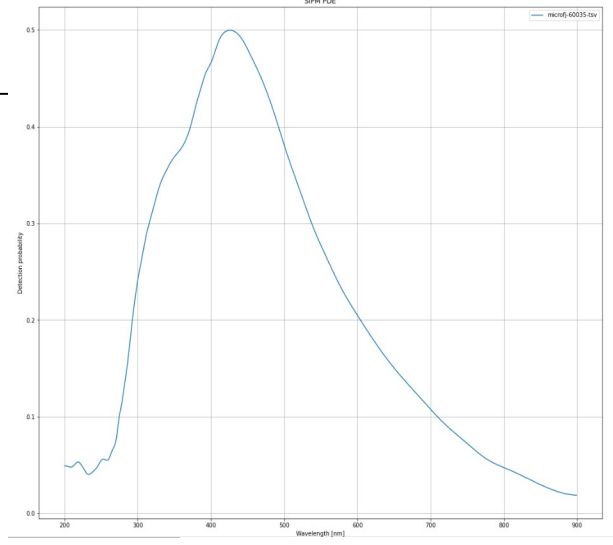
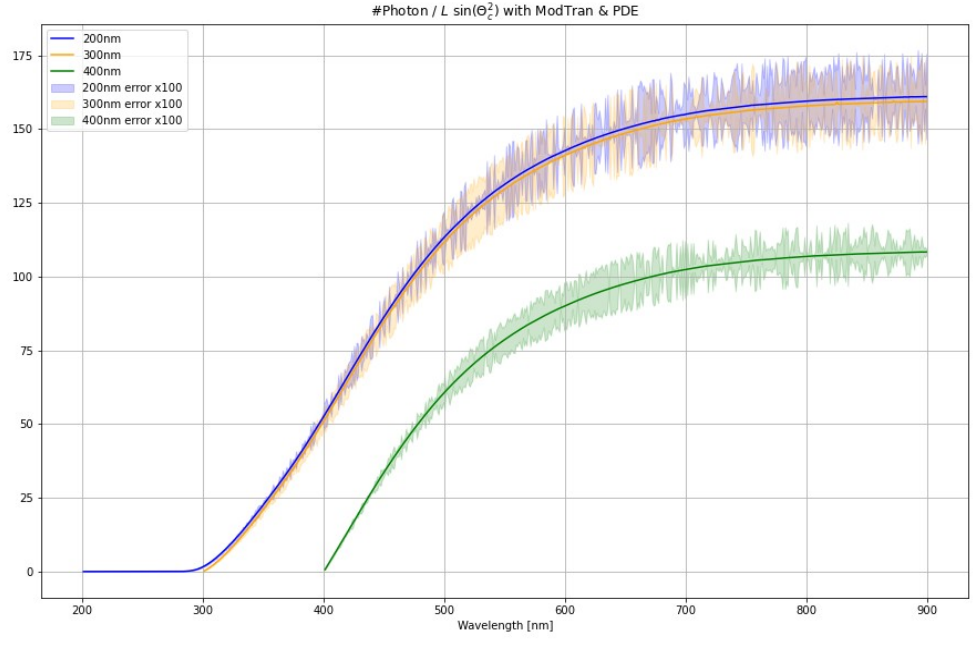
Computing Structure







GPU based photon p

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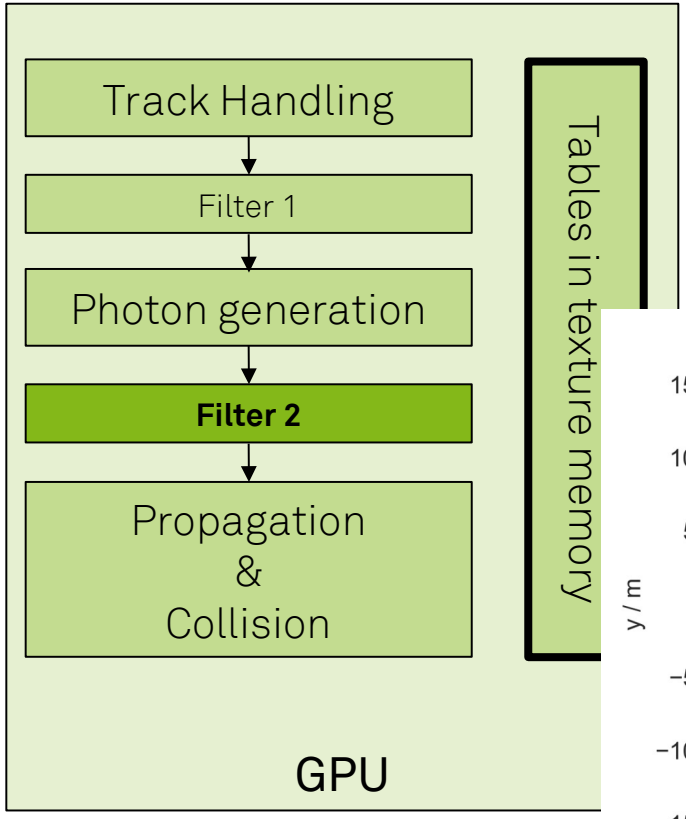
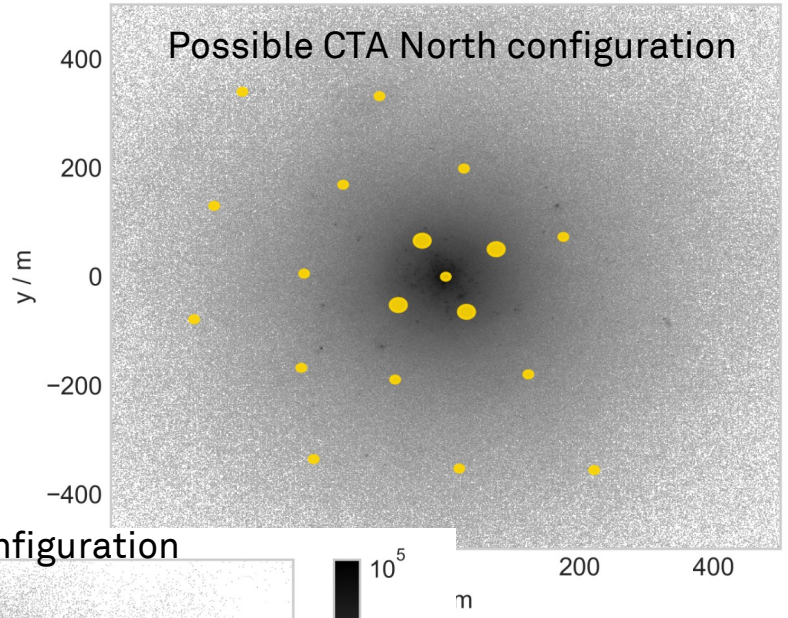
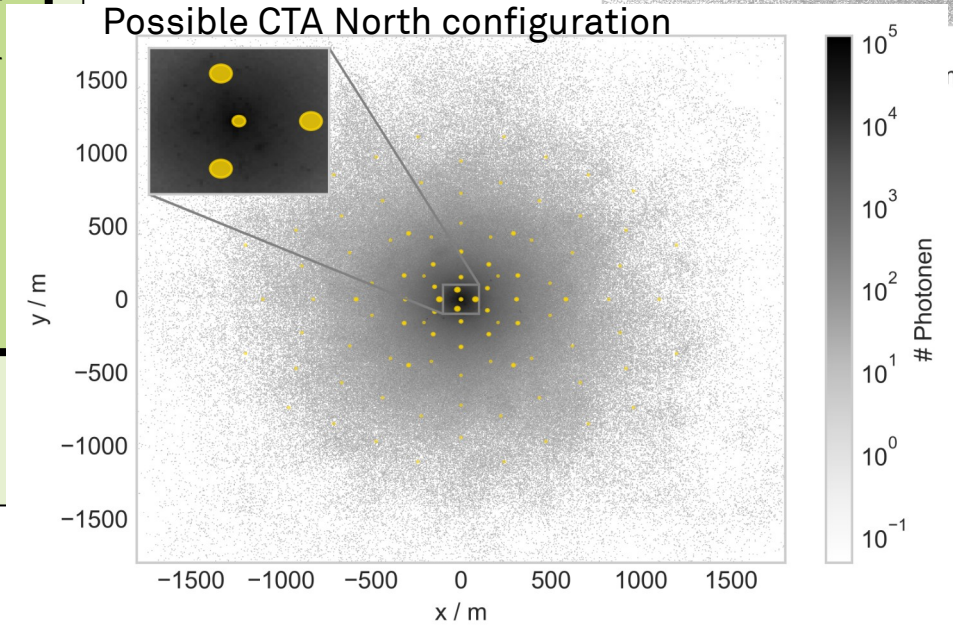
Computing Structure







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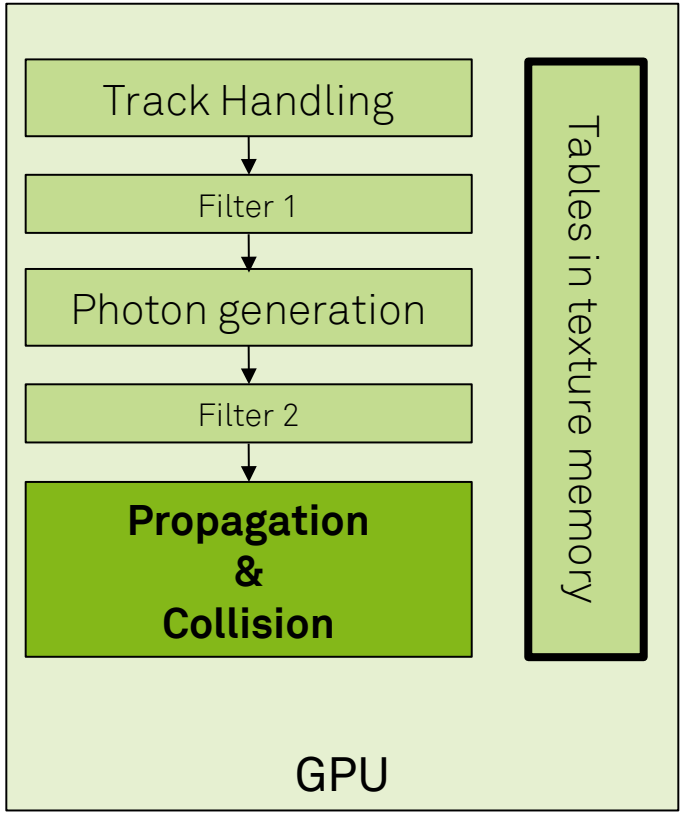
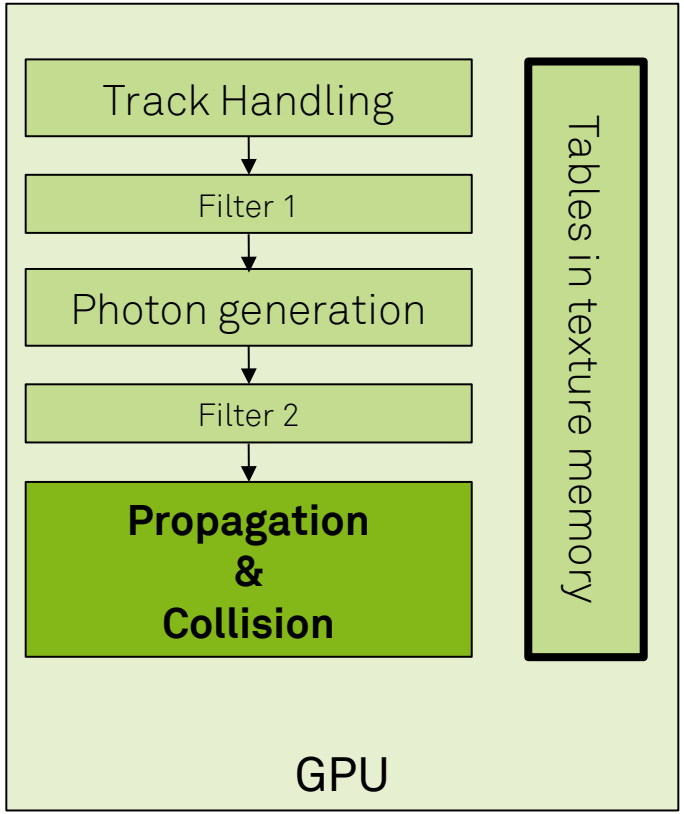
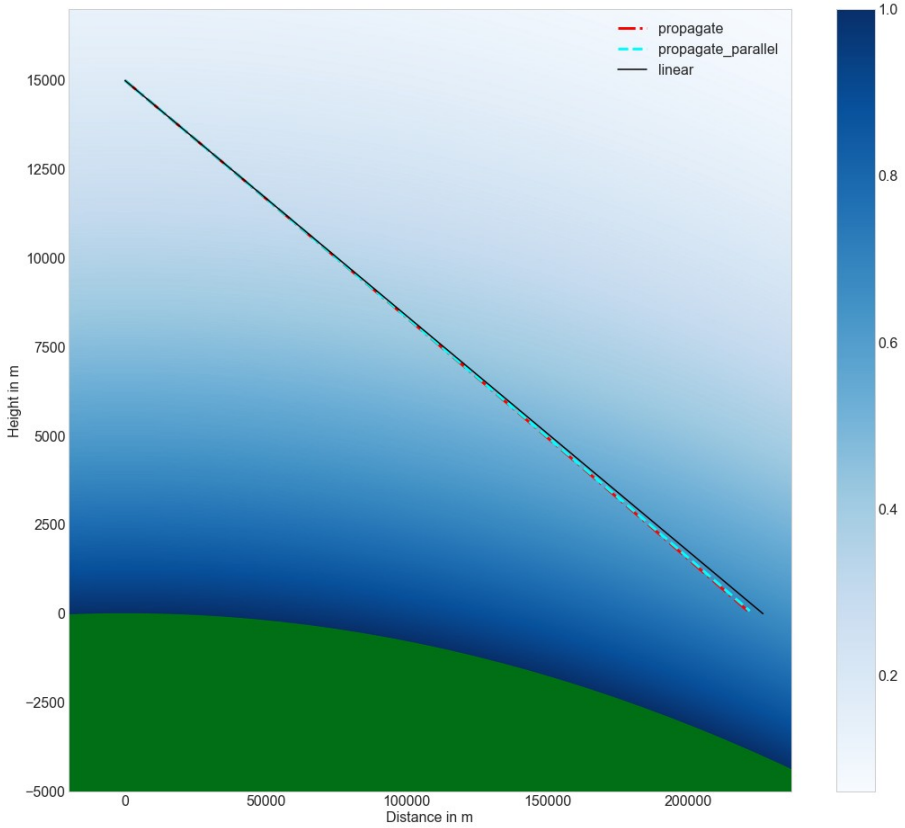


- Propagation linear in first order …

… but corrections necessary for modern IACT's

Computing Structure





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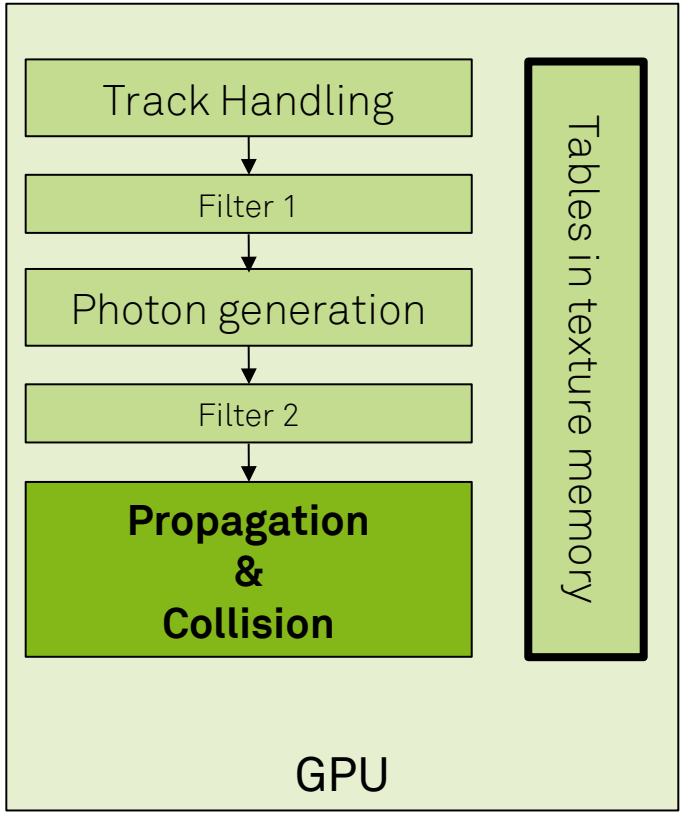

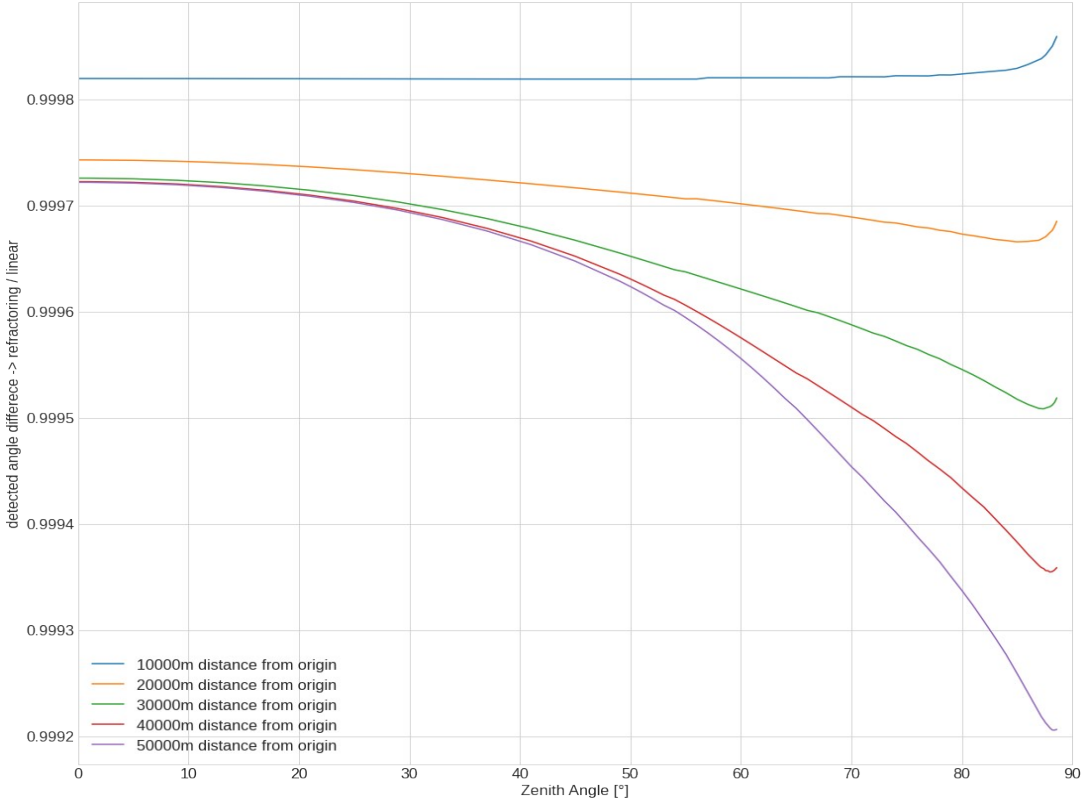

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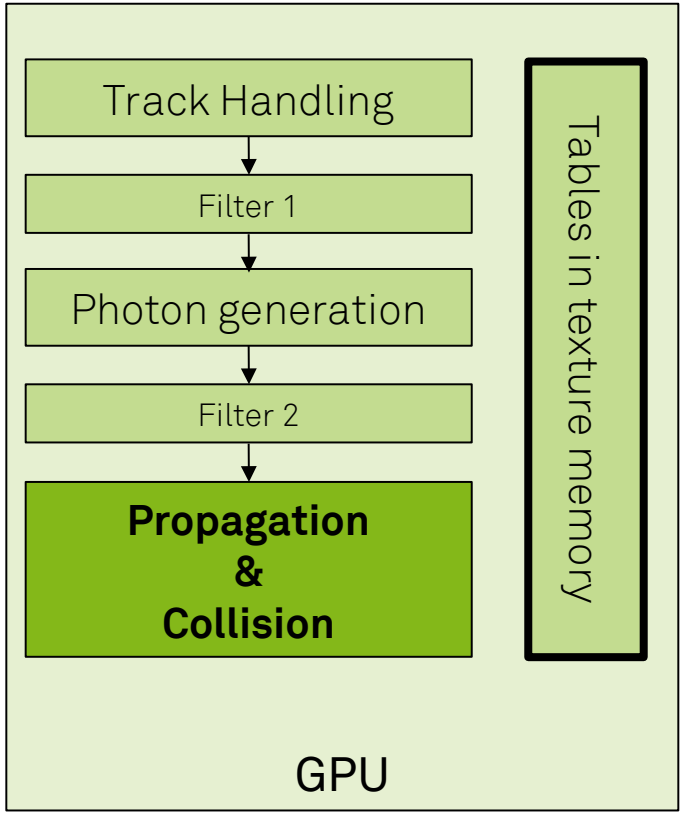

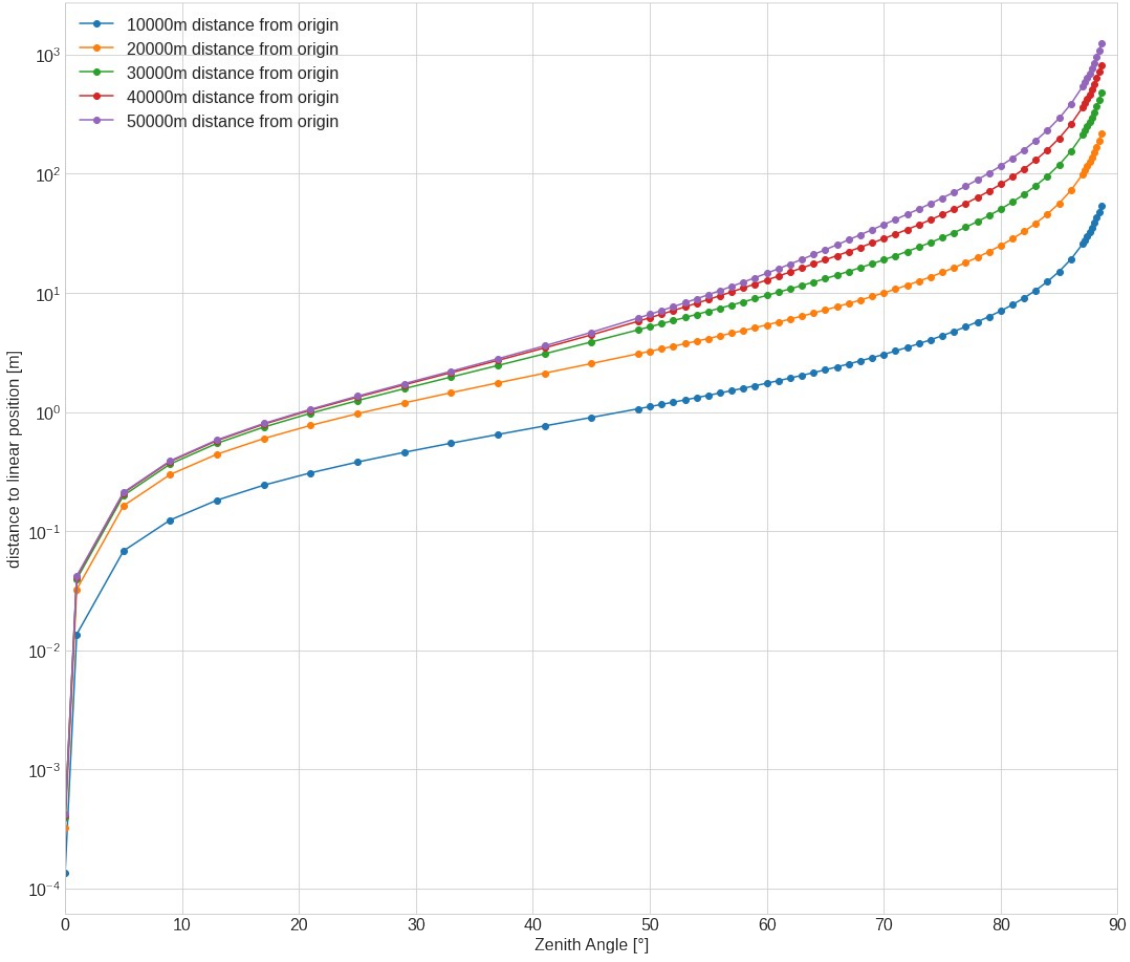

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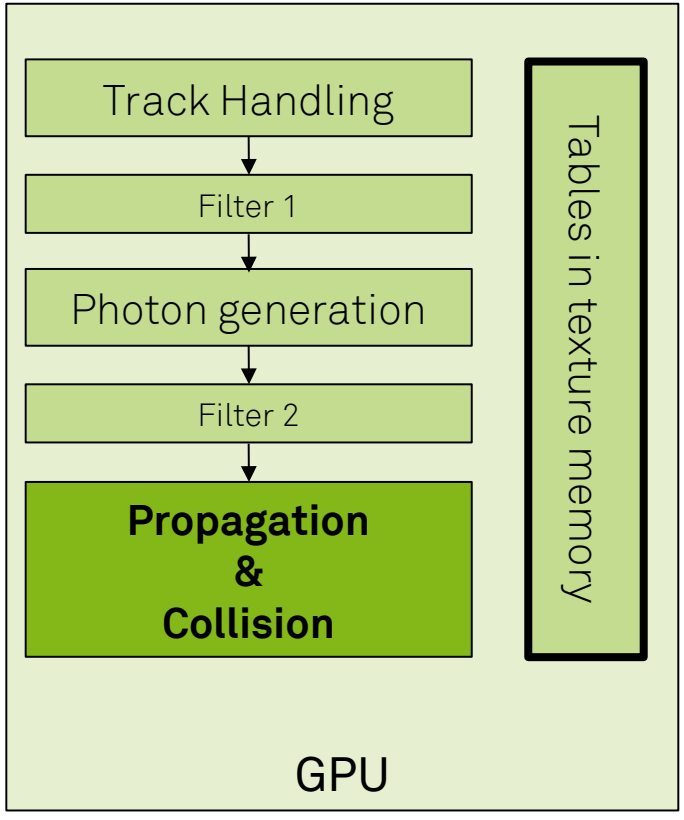

- Propagation linear in first order
- Tabulated correction factors generated offline and applied on GPU

Conclusion & Outlook

- GPU based light propagation possible and likely fast than CPU based approach
- Corsika 8 is a open source and modular framework for cosmic ray simulation: https://gitlab.ikp.kit.edu/AirShowerPhysics/corsika
- In Vivo tests still necessary with very new EM-Model (Proposal) for Corsika8
- Improvement by sorting to reduce “starvation” of threads or more efficient thinning
- Dedicated test of a more efficient fluorescence propagation