Massively parallel code to search for gravitational waves from rotating neutron stars in advanced detector data

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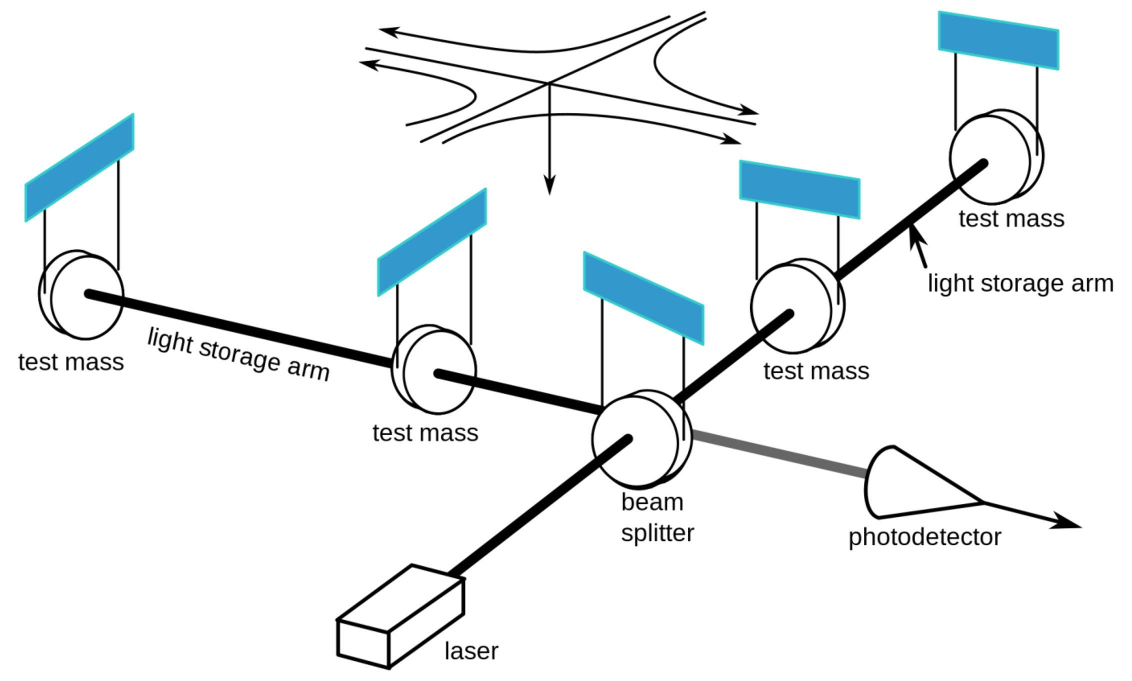
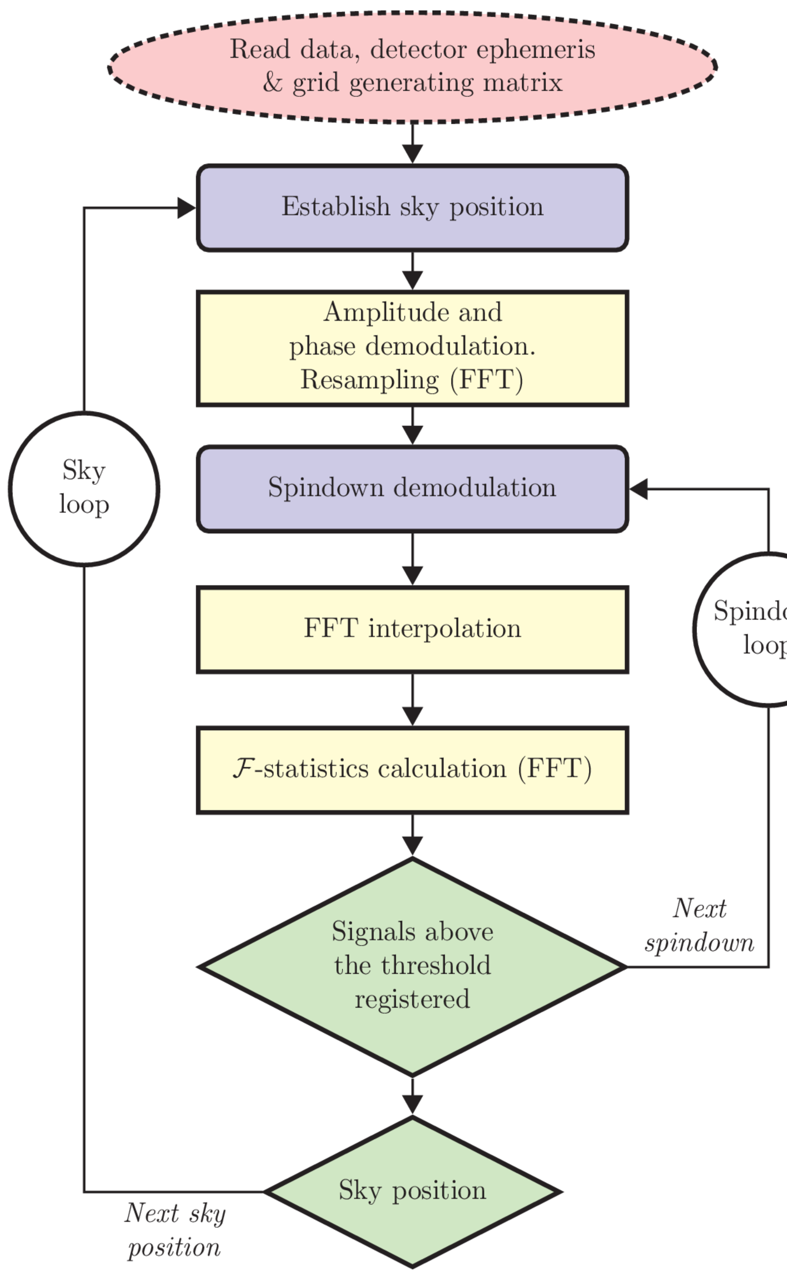
Direct detection of gravitational waves

The last prediction of general relativity still awaiting a direct experimental verification. Observations of gravitational waves will open a new field - gravitational wave astronomy. First science data from the global network of advanced gravitational wave detectors - **LIGO**, **GE0600** and **Virgo** kilometre-long arm interferometers, are expected in July 2015.

The **Advanced Detector Network** will be sensitive to signals all over the sky; source positions can be determined by triangulation. For these reasons, searching for unknown sources in noisy data is algorithmically challenging, since one has to simultaneously look for different types of signals, and computationally intense, due to the large parameter space over which the searches must be carried out.

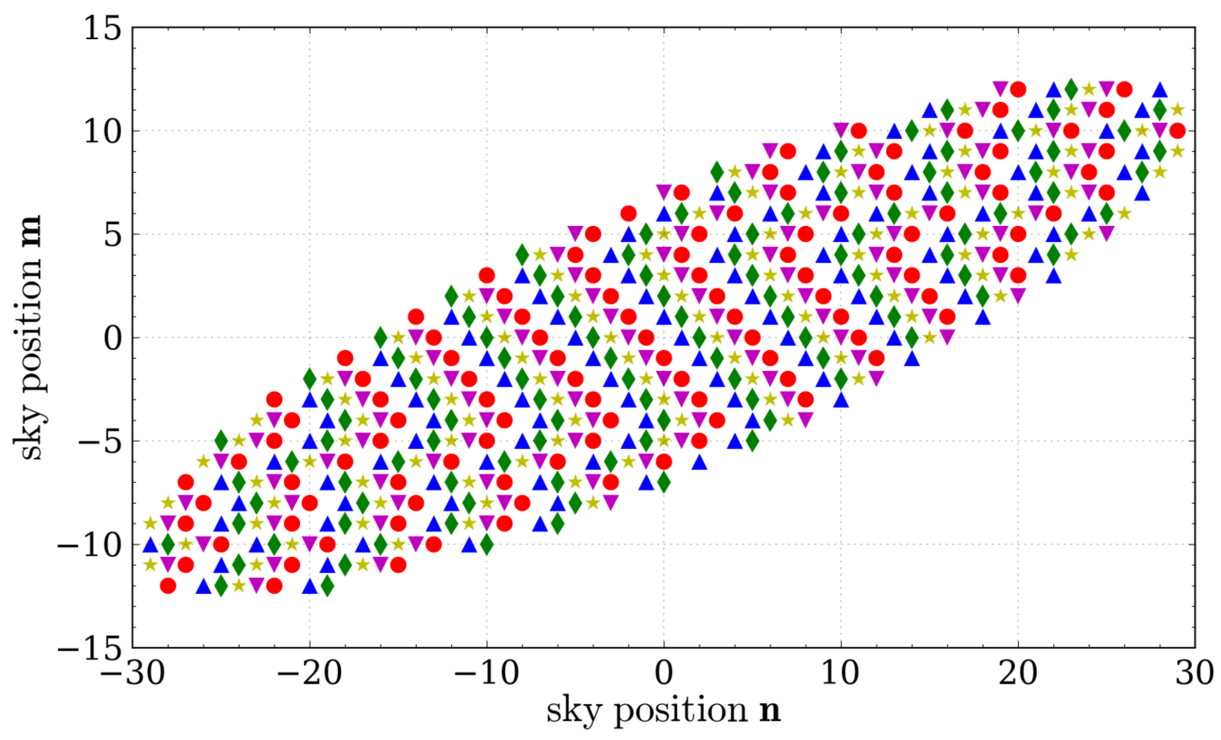


Continuous gravitational waves from rotating neutron stars
Parallelised polgraw-allsky code and skyfarmer for massive parallel runs

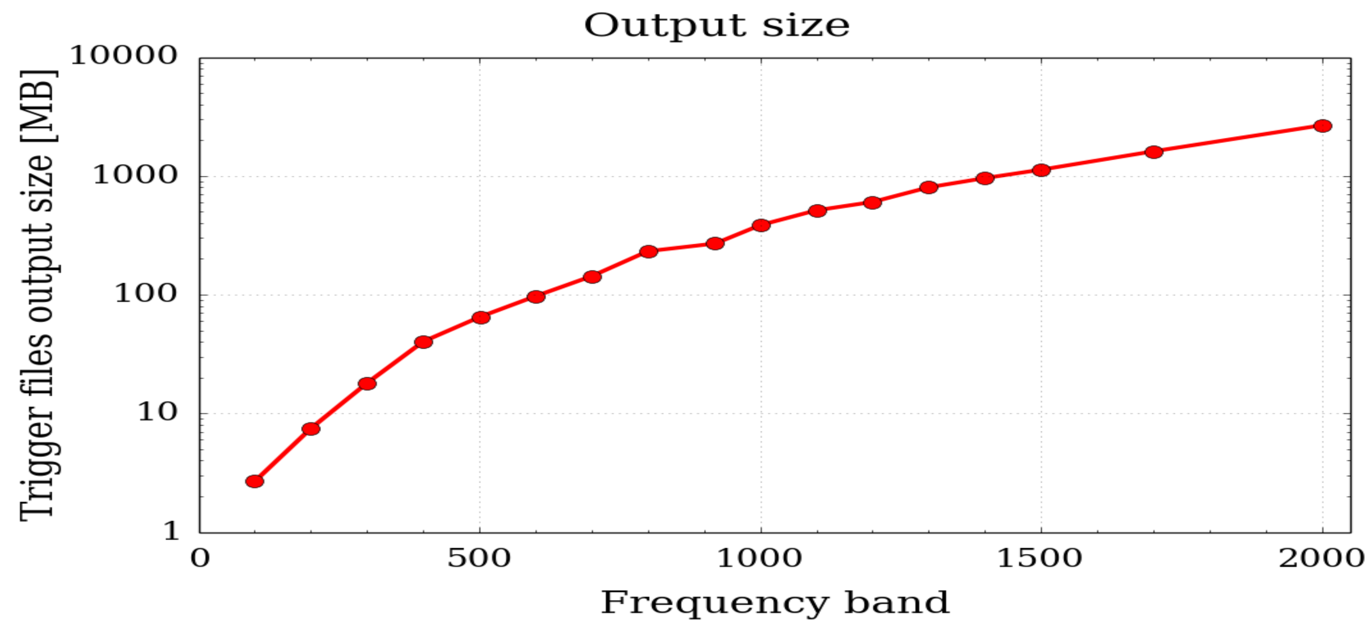


Flowchart of the single-frequency search with polgraw-allsky code

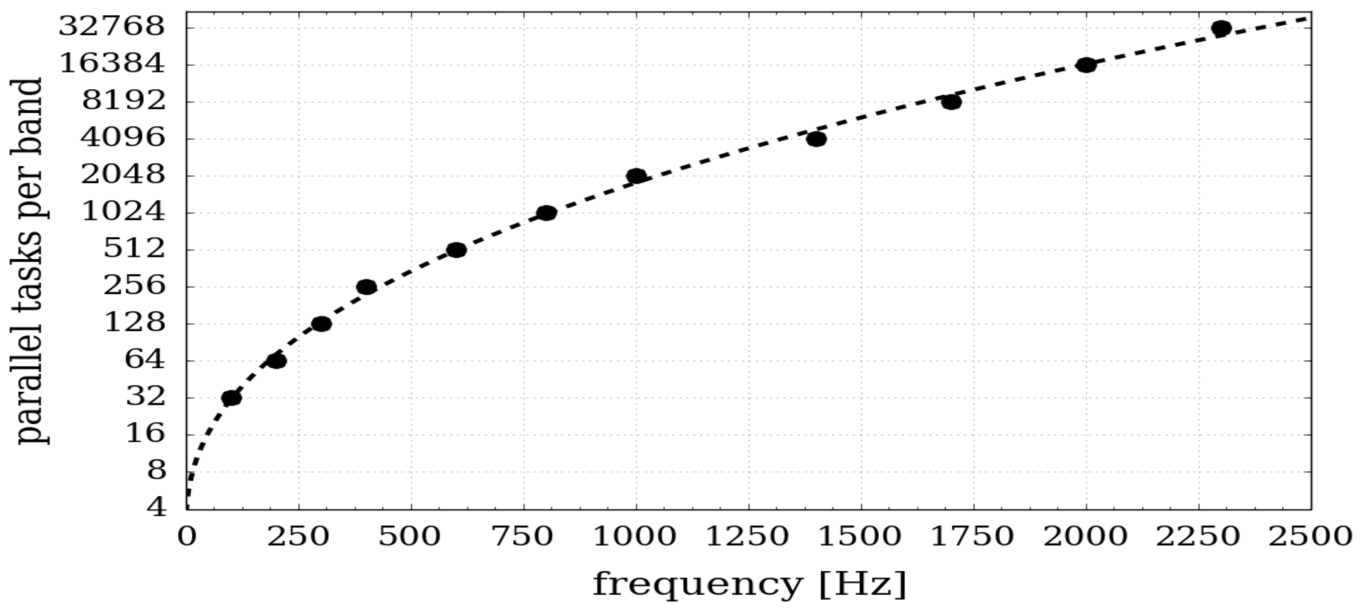
We analyse narrow frequency (1 Hz), long duration (~1yr) time series with a match-filtering maximum likelihood method, **F-statistics,** in a frequency range **f** 10 Hz – several kHz. Computational expense grows like $\mathbf{f^3}$.



Covering the sky positions for a given search frequency using the parallelized polgraw-allsky. Colours denote different computing tasks. Here six parallel tasks are active and are repeatedly covering the whole hemisphere based on the round-robin scheduling algorithm.

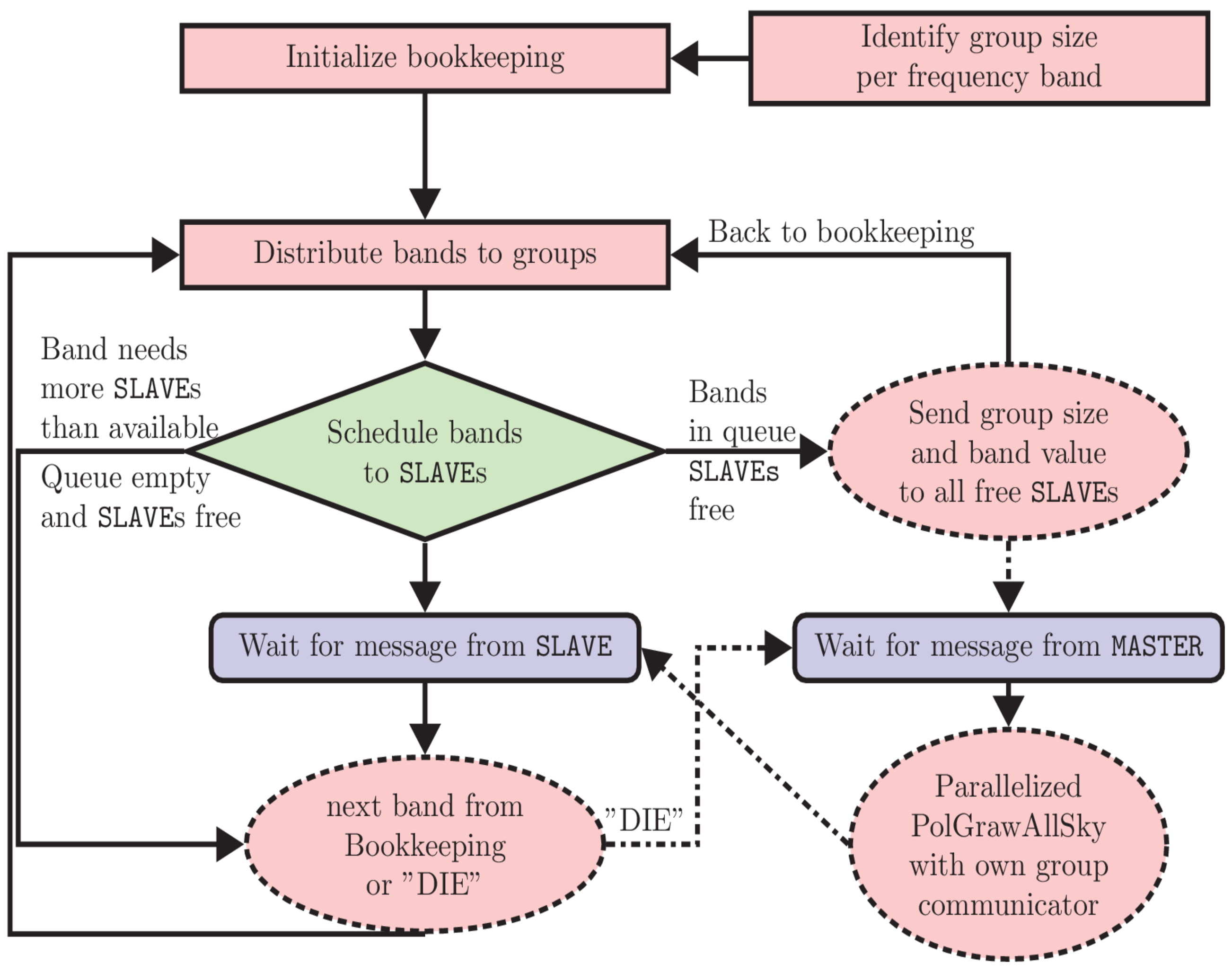


Size of simulated output data and maximal scalability per frequency



- **Estimated computer cost for polgraw-allsky in the incoming Advanced Era of Detectors is 1000 Million CPU hours**
- **To analyse data in acceptable time scale, use of massively parallel systems with PetaFlop performance and more is inevitable**

Task farming for higher scalability of multiple parallel runs



*Flowchart of the **skyfarmer**. Implementation of task farmer algorithm for running multiple runs of parallel polgraw-allsky search codes at different frequencies as a one massively parallel computation with up to 50000 parallel tasks.*

The structure of the skyfarmer is divided into five main parts:

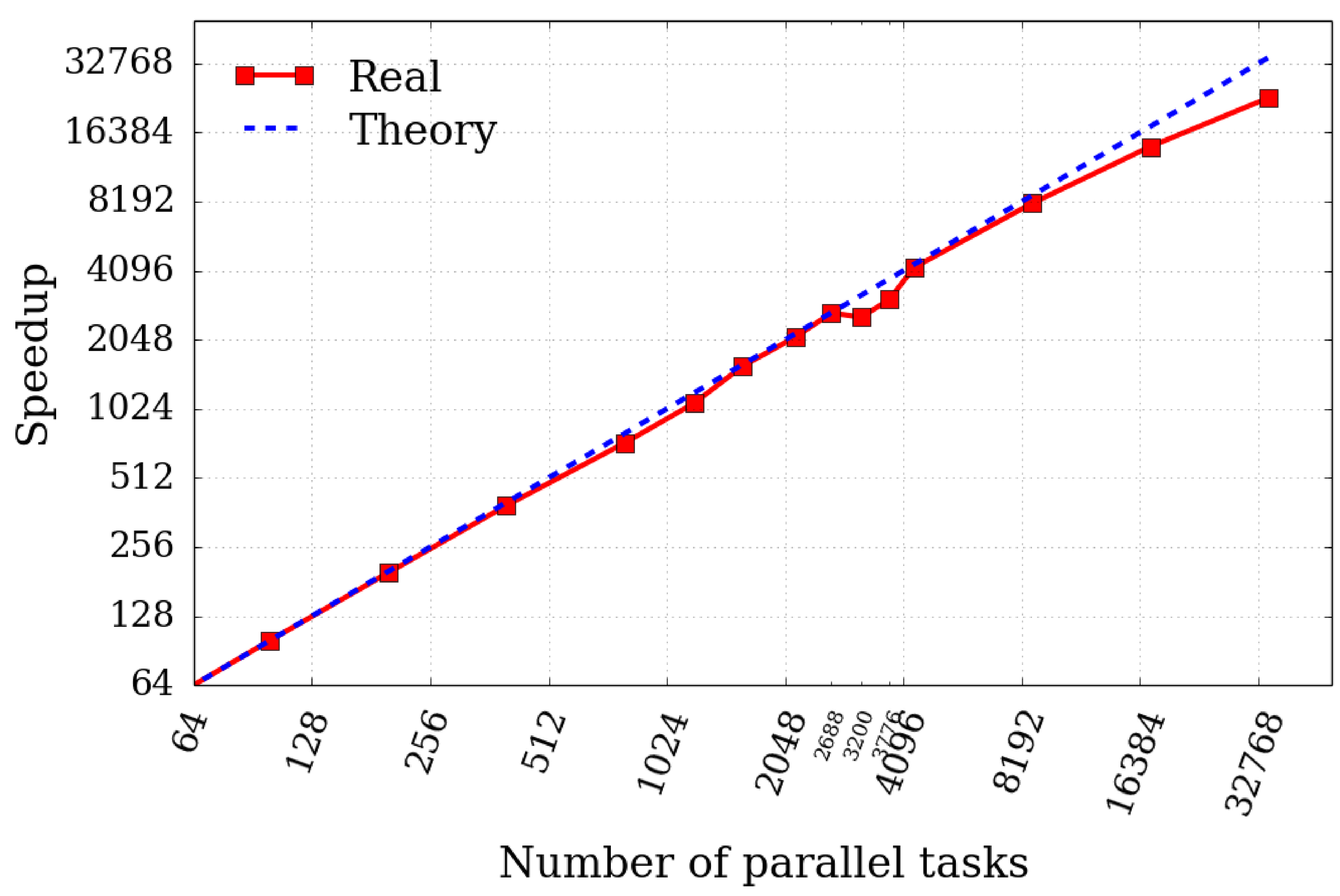
1. initialization and estimation of the available and necessary parallel resources,

2. construction of different tasks as groups for requested frequencies,

3. distribution and decomposition of groups

4. bookkeeping information about free and busy resources,

5. execution of the parallel PolGrawAllSky code.



Speed-up test: reduction of the number of CPU hours for the same-size simulations by increasing the number of parallel tasks, performed with the skyfarmer, shows that Scheduling algorithm for grouping and distribution of tasks is still suboptimal

- **Optimization and Hybrid Parallelisation is crucial to reach optimal and advanced scalability**
- **Implementation of parallelized pollgraw-allsky for using co-accelerator cards will allow to reach higher performance**
- **Nvidia CUDA GPU version speed-up x100 w.r.t. serial single core version, work in progress**

Advanced analysis are performed on supercomputing facilities at HLRS in framework of joint Research and Development project ID 12968 of Simulation Laboratory (SimLab) for Elementary- and Astro- Particle Physics of Karlsruhe Institute for Technology. SimLabs are teams of High Performance Computing experts at KIT and Forschungszentrum Jülich working with different scientific communities in adaptation of scientific simulation codes into HPC systems at extreme scales.