

# HPC with GPUs in LHM

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## Motivation

LHC experiments are increasingly collecting larger amounts of data to be analyzed. Storing these large volumes is computationally expensive and also need to use high Performance Computing techniques to reduce the overhead of the analysis. GPUs usually have ~10 cores while CPUs have ~1000, making them very well suited to accelerate several steps of the analysis.

## Core ideas

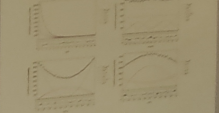
- Minimize the amount of data transferred between host and device when possible, since it will reduce latency thanks to the GPU with its special high bandwidth, as possible between the host and the device when using high-speed or "global" memory.
- Optimize per transfer overhead by packing many small transfers into one larger transfer.
- Outsource I/O transfers whenever it is possible properly handling kernel execution.

## Theoretical model

The physical PDF is given by:  
$$P^{(H)}(q, k) \propto e^{-\frac{1}{2}(A_{11}q^2 - A_{12}k^2) \cos(\phi)}$$
  
$$2 \sin(\frac{1}{2}(A_{11}q^2 - A_{12}k^2) \cos(\phi))$$
  
$$e^{-\frac{1}{2}(A_{21}q^2 - A_{22}k^2) \cos(\phi)}$$
  
$$2 \sin(\frac{1}{2}(A_{21}q^2 - A_{22}k^2) \cos(\phi))$$
  
being  $\phi = \pi$  the factor. If the decay time is  $\Delta$ , the position in phase space. The amplitude model is a superposition of quantum helicity states:  
$$A_{ij}(q, k) = \sum_{\lambda} a_{ij\lambda} e^{i\lambda \phi}$$

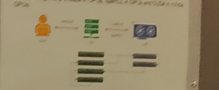
## $\chi^2$ analysis

- Golden channel to measure the  $\tau_{12} = 0.258 \pm 0.005$  and  $\phi$  with oscillation phase, determining carrier mass energy.
- Large amounts of LHC data to be fitted with a 4D model (two and three helicity angles). These weights are significant for our and other category.
- Good decay time resolution, to capture LHC capabilities.
- Modeling the decay time dependence of the efficiency.
- Modeling reconstruction and selection efficiency on the three helicity angles.



## What is genemu?

- Genemu is a python package used as interface to remote hardware devices (or several devices).
- Provides a custom CMake-based library interface with common user functions and implements complex functions and computations.
- Has a flexible configuration system to adapt to different hardware configurations and parameters, configurable through environment variables.
- Easy to use interface to perform parameter optimization.
- Compatible general interface to GPUs, CPUs or FPGAs or other hardware devices.

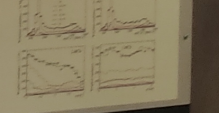


## Experimental effects

Power trigger reconstruction system, hardware:  
$$P = \frac{1}{2} (1 + \cos(\phi))$$
  
We have to take into account two experimental effects:  
$$P^{(H)}(q, k) \propto e^{-\frac{1}{2}(A_{11}q^2 - A_{12}k^2) \cos(\phi)}$$
  
Angular acceptance, detector geometry and selection procedure (reconstruction) and the trigger system. We need to consider the effect of an angular acceptance model.  
This acceptance trigger selection introduces a decay time bias. A time acceptance model is needed to consider the effect.  
Time resolution: the PDF has to be convoluted with an acceptance model to account for the time resolution of the detector.

## $\chi^2$ analysis

- Model for events in  $\tau_{12}$ .
- Model for PDF very sensitive to these PDFs.
- Efficient factor analysis (EFA) in 4D.



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