Speeding up MadGraph5 with GPUs

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In collaboration with:
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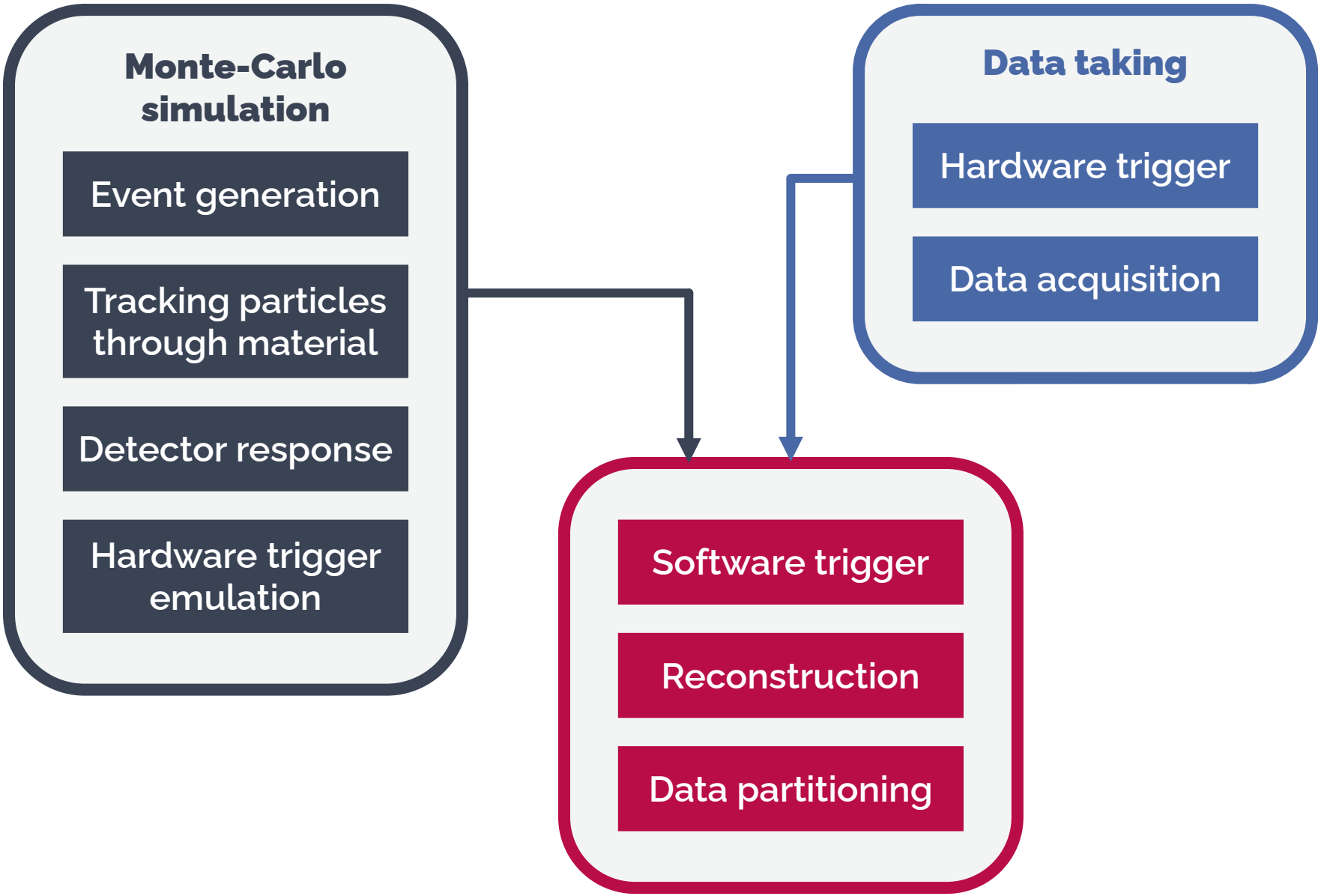
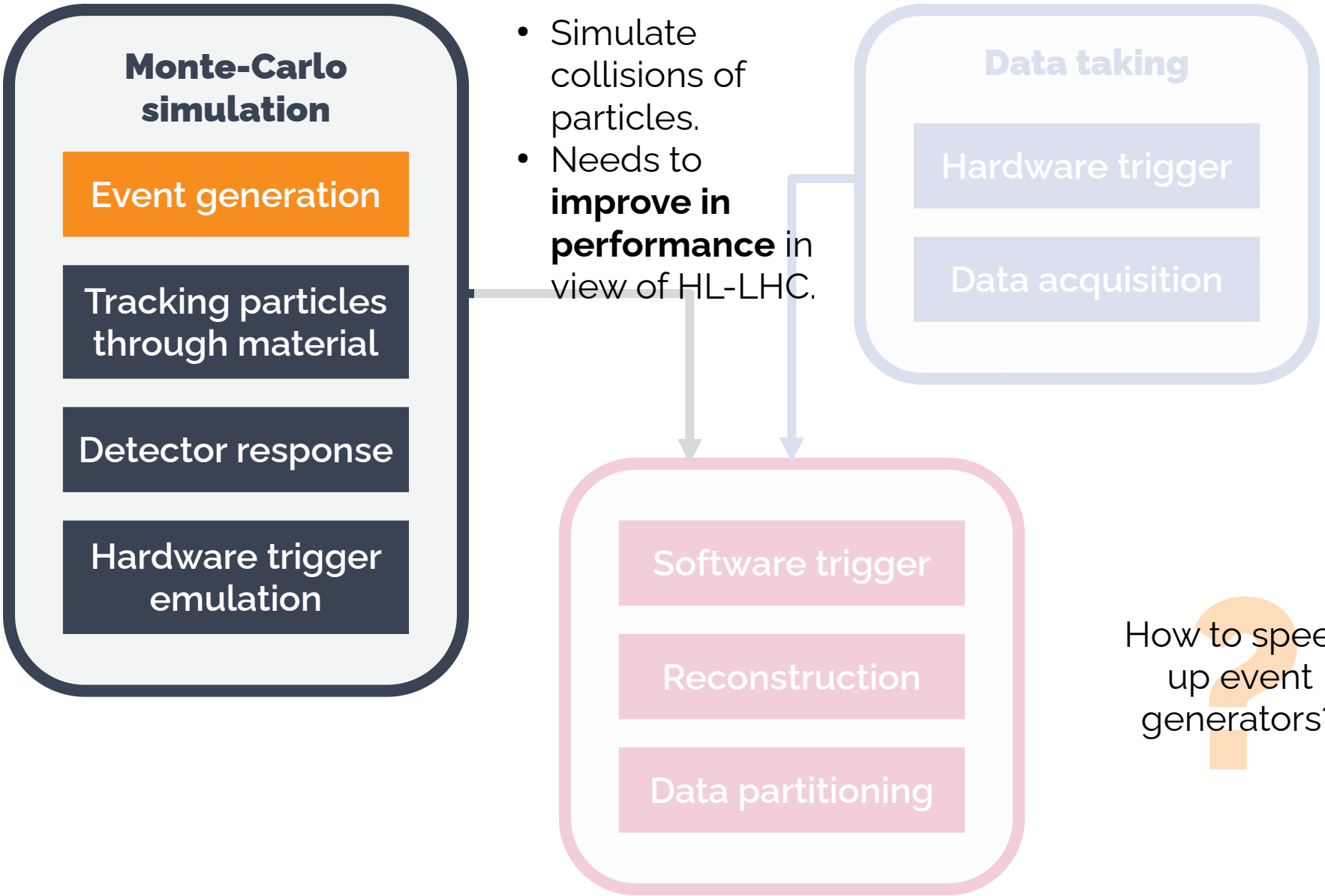
Physics search workflow



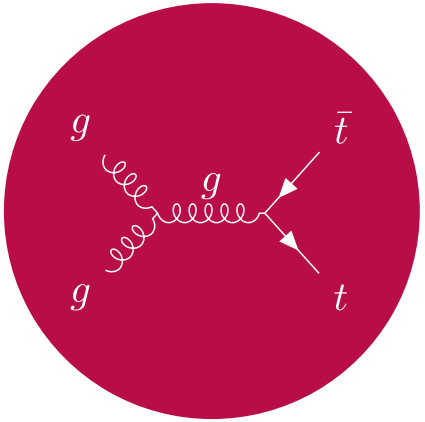
Physics search workflow



GPUs

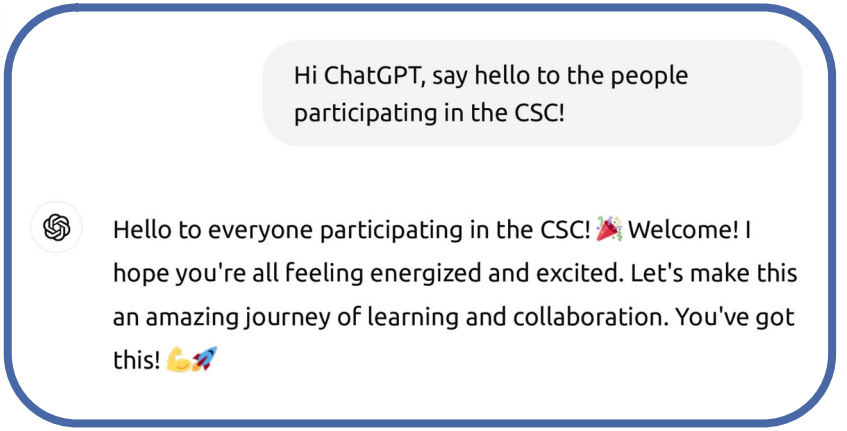
Cryptocurrencies

MineCraft w/ shaders



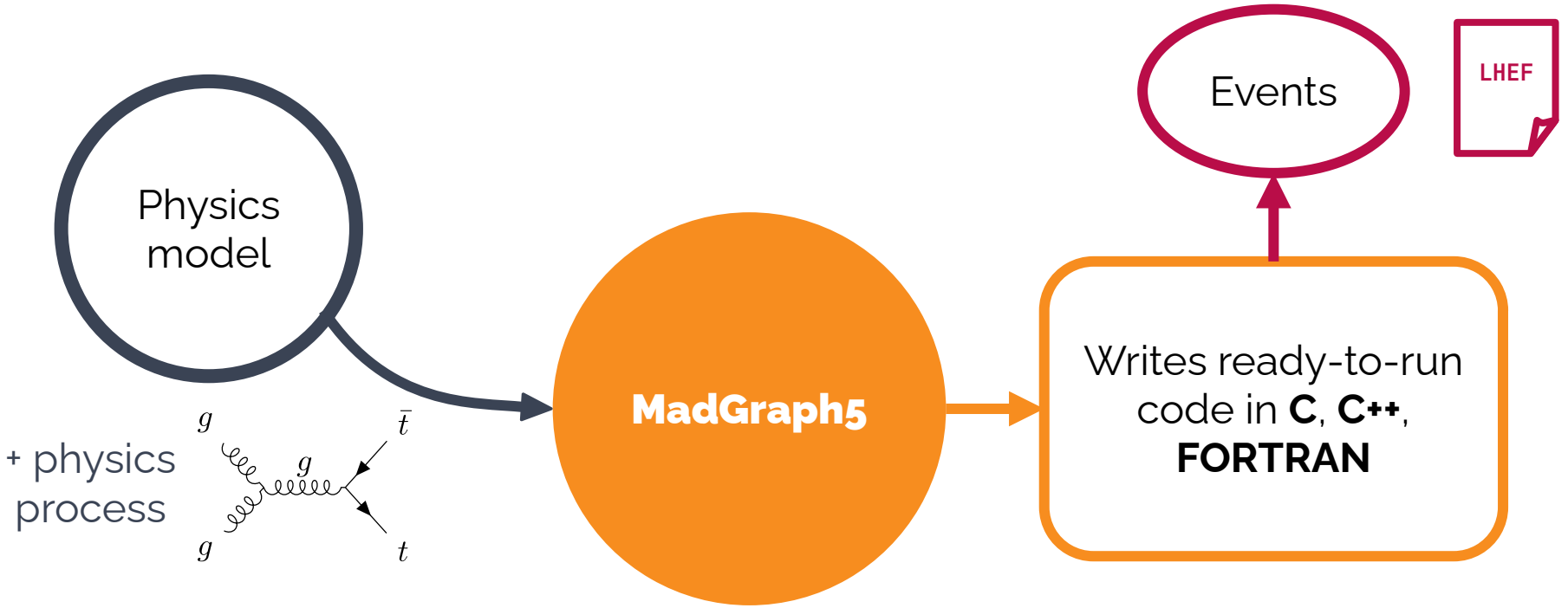
Scientific computing

LLM



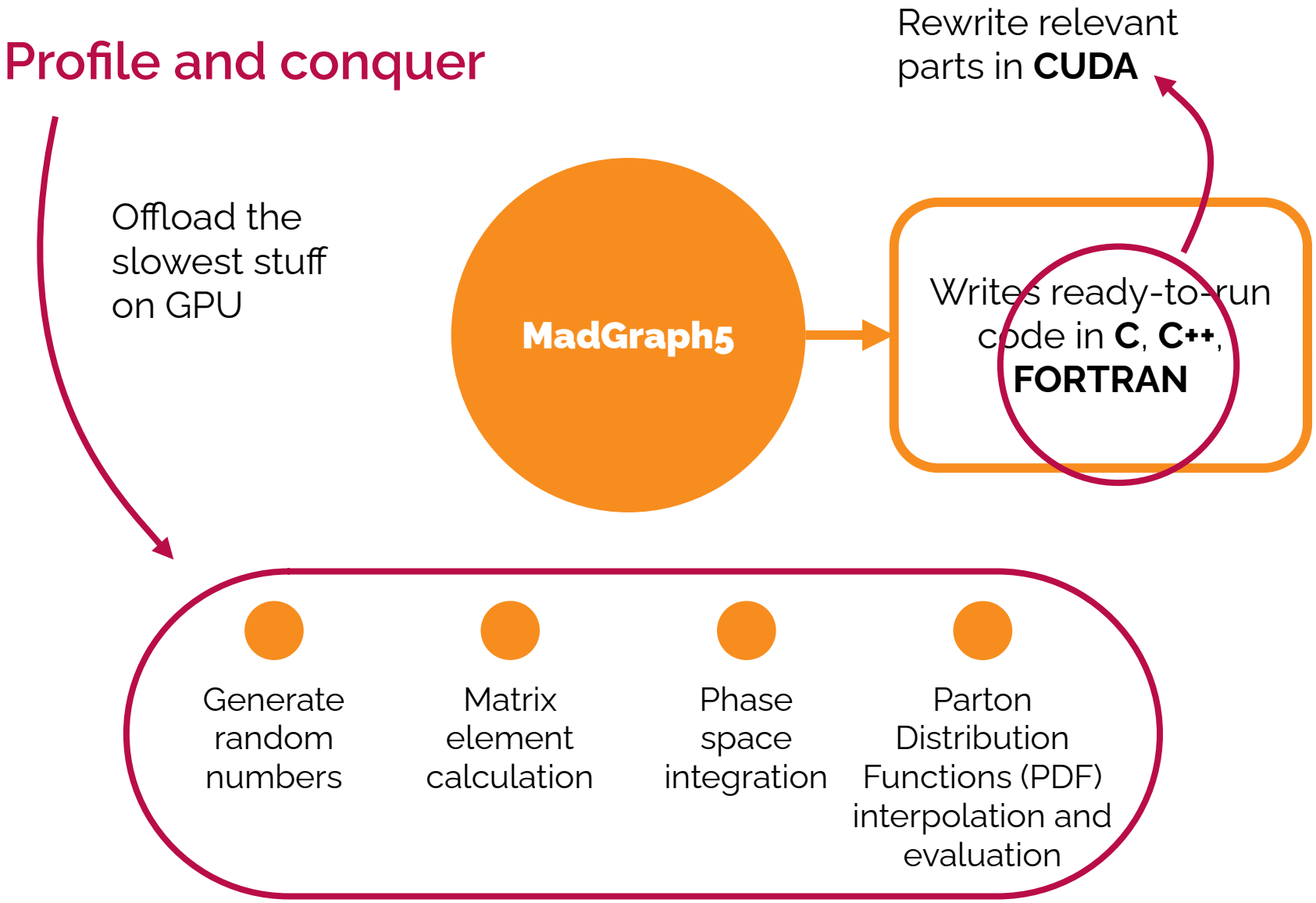
MadGraph5

[J. Alwall, M. Herquet, F. Maltoni, O. Mattelaer, and T. Stelzer. JHEP 06 (2011), p. 128]
[J. Alwall et al. JHEP 07 (2014), p. 079]



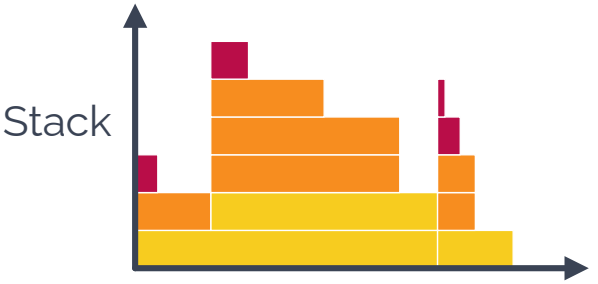
- Generate random numbers
- Matrix element calculation
- Phase space integration
- Parton Distribution Functions (PDF) interpolation and evaluation

MadGraph5


Profile and conquer
Rewrite relevant parts in **CUDA**
Offload the slowest stuff on GPU
MadGraph5
Writes ready-to-run code in **C**, **C++**, **FORTRAN**
Generate random numbers
Matrix element calculation
Phase space integration
Parton Distribution Functions (PDF) interpolation and evaluation

MadGraph5

Profile and conquer

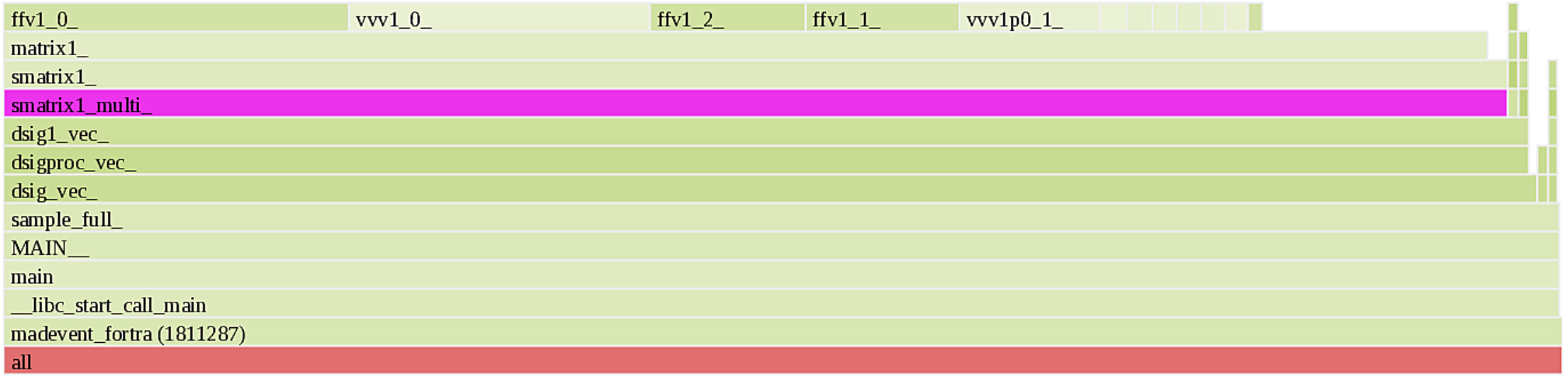


Flamegraphs!

- Generate random numbers
- Matrix element calculation
- Phase space integration
- Parton Distribution Functions (PDF) interpolation and evaluation

$gg \to t\bar{t}gg$: FORTRAN

~ 97% running time



Generate random numbers

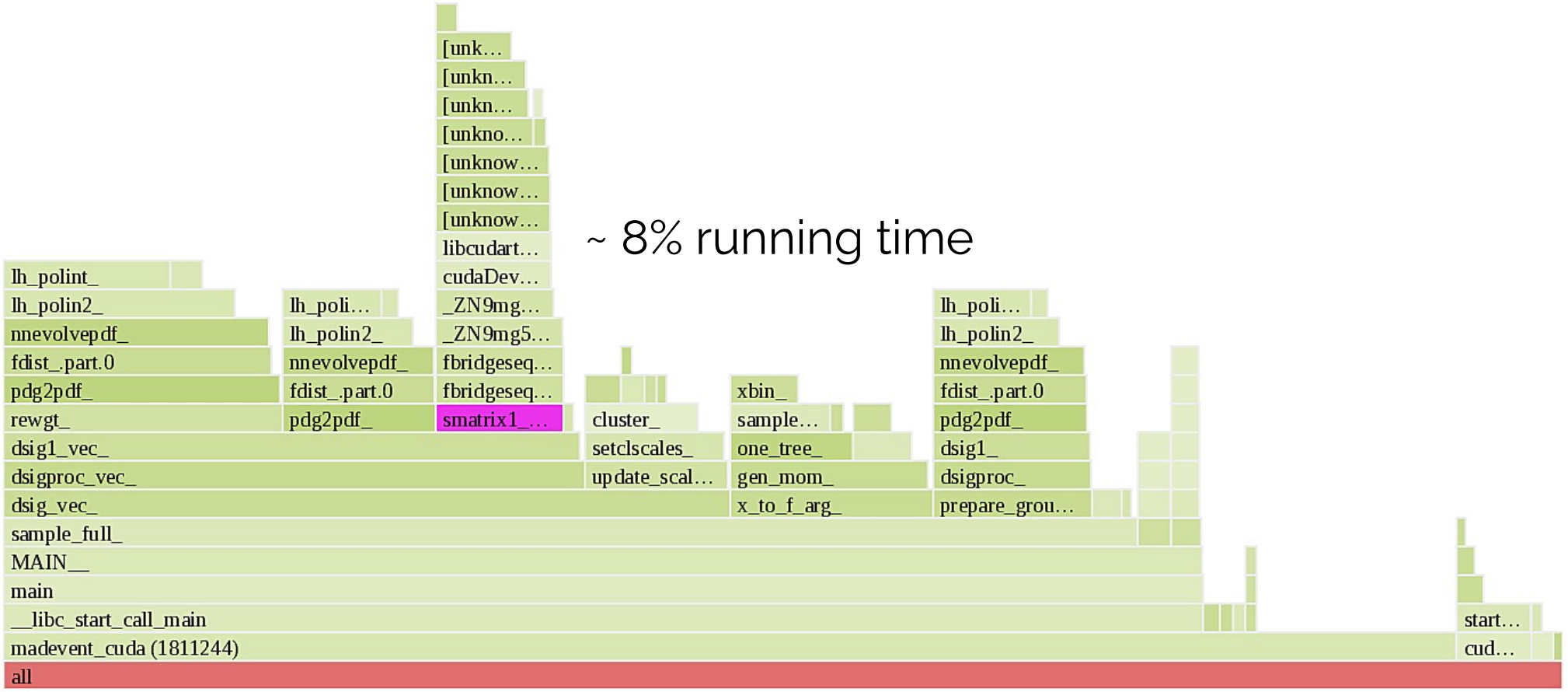
Matrix element calculation

Phase space integration

PDF interpolation and evaluation

Offload to GPU

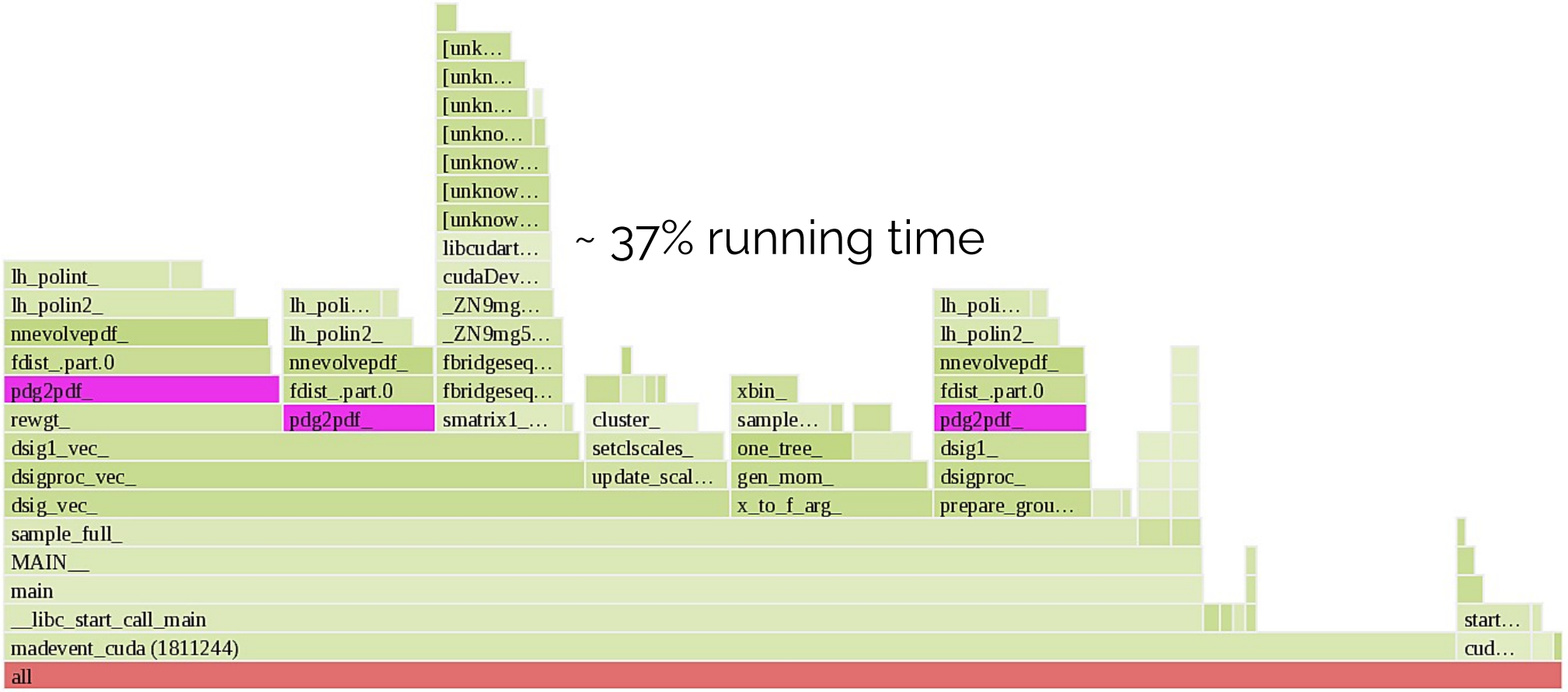
$gg \to t\bar{t}gg$: CUDA



~ 8% running time

[S. Hageboeck et al. EPJ Web Conf. 295 (2024), p. 11013]
[A. Valassi et al. ACAT 2022 (2023)]

$gg \to t\bar{t}gg$: native PDF



~ 37% running time

Generate random numbers

Matrix element calculation

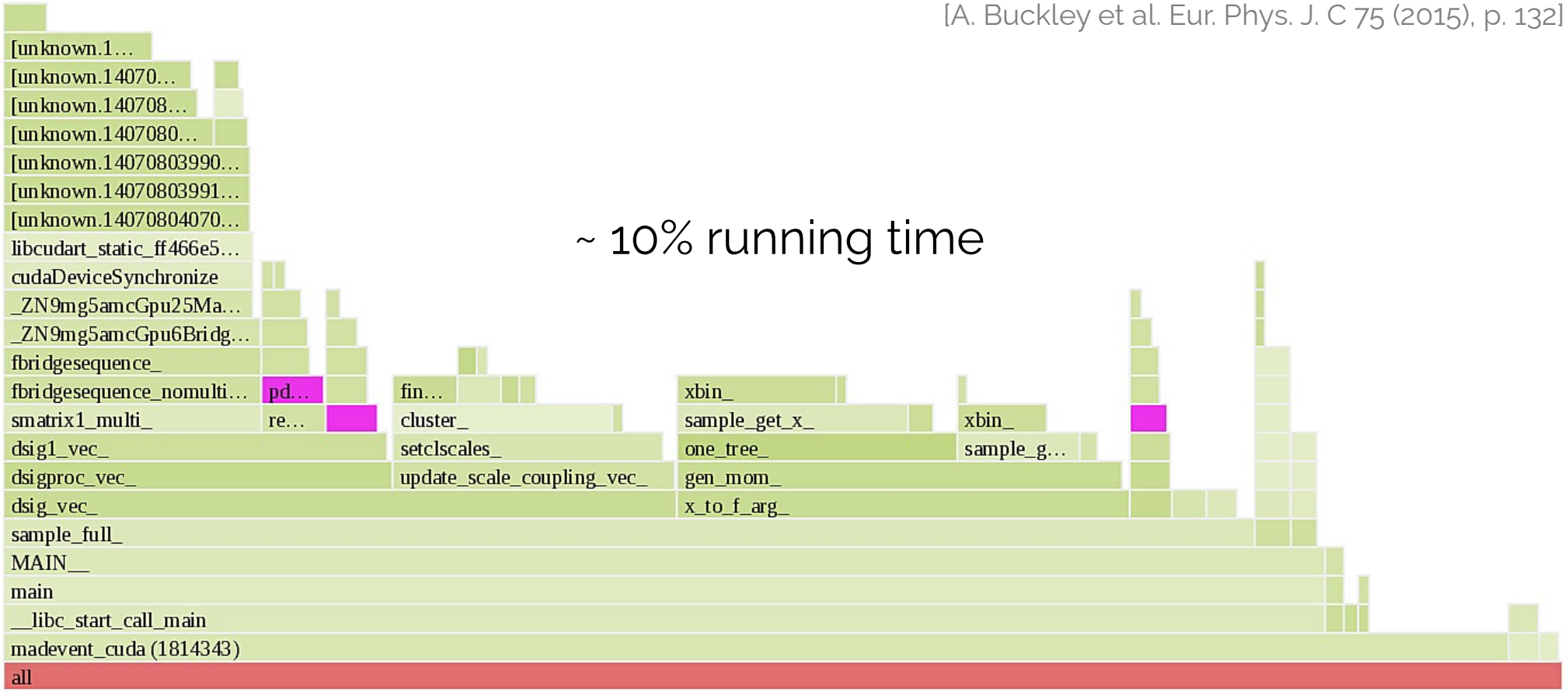
Phase space integration

PDF interpolation and evaluation

Use external library LHAPDF (C++)

$gg \to t\bar{t}gg$: LHAPDF

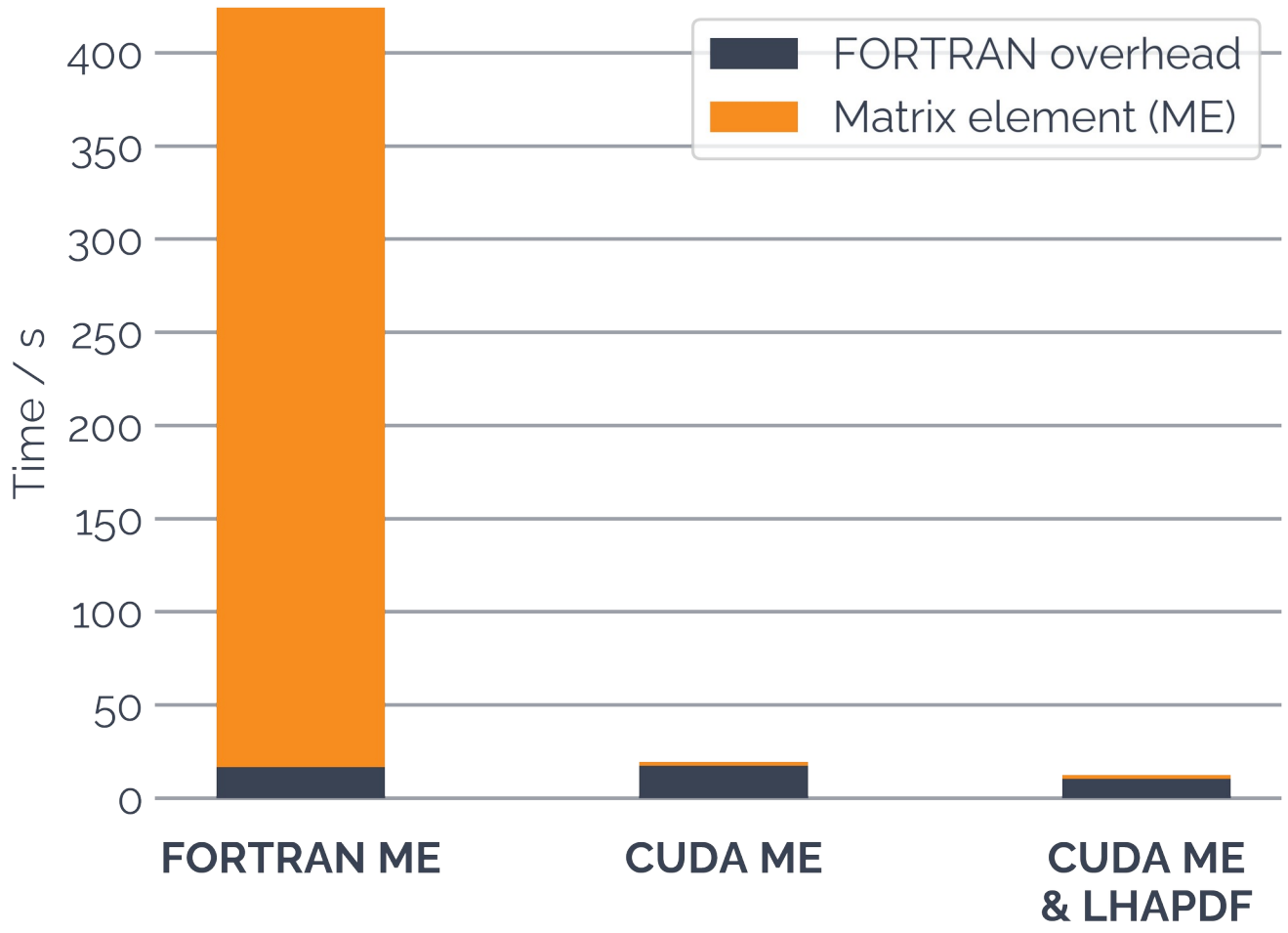
[A. Buckley et al. Eur. Phys. J. C 75 (2015), p. 132]



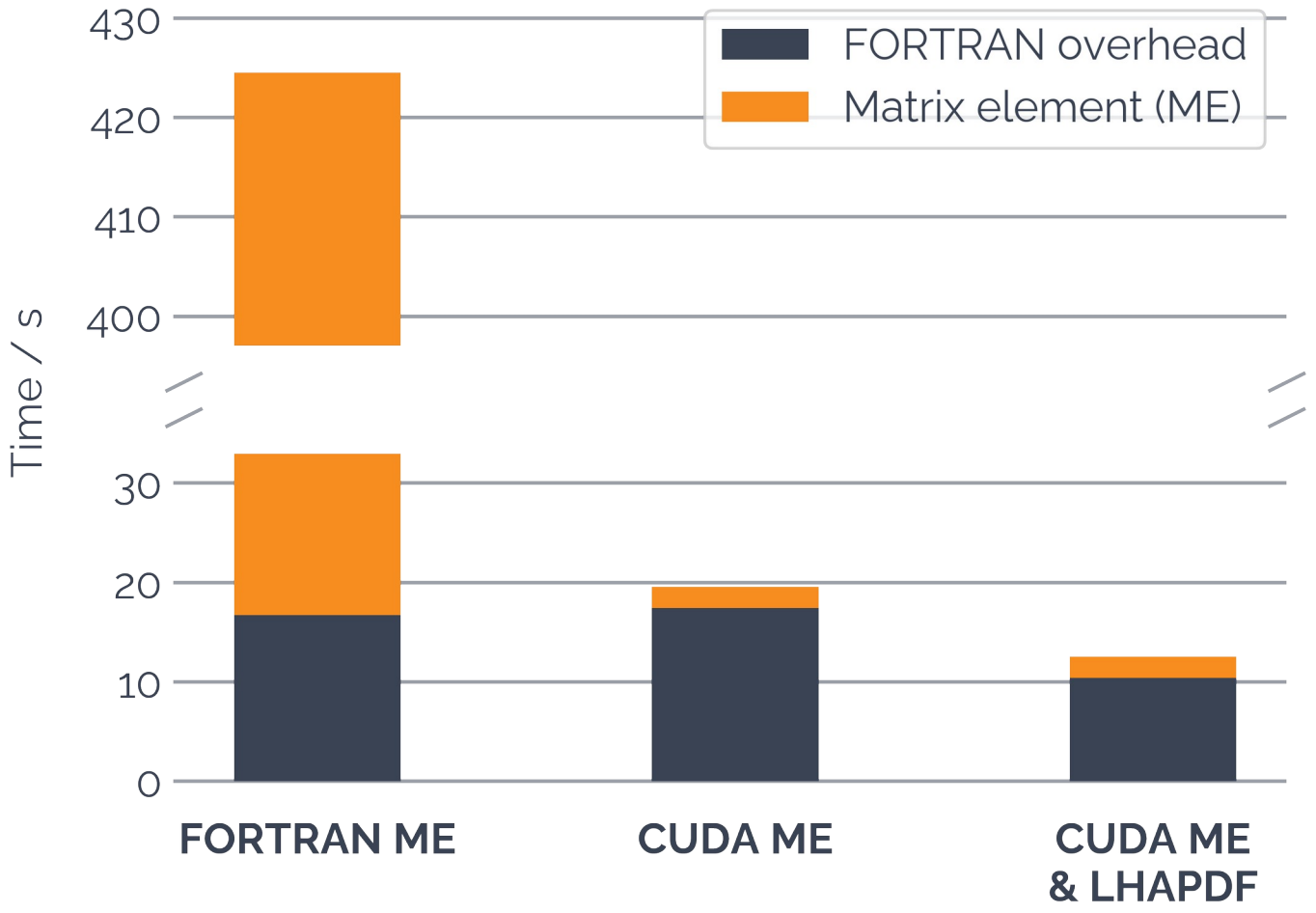
~ 10% running time

Next: try GPU implementation of LHAPDF.

Time comparison



Time comparison



Conclusions

- GPUs allow obtaining a significant speed up of MadGraph.
- The computations on GPU are so fast that most of the time the GPU is idle:
  - ➔ try to offload more stuff (PDF evaluation, phase space integration).
- Very close to release.