GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
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Plan de Recuperación, Transformación y Resiliencia
AGENCIA ESTATAL DE INVESTIGACIÓN
IFIC INSTITUT DE FÍSICA CORPUSCULAR
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
VNIVERSITAT DE VALÈNCIA

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Porting MADGRAPH to FPGA

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Instituto de Física Corpuscular (CSIC-UV)

1st FPGA Developers' Forum (FDF) meeting

June 12th, 2024

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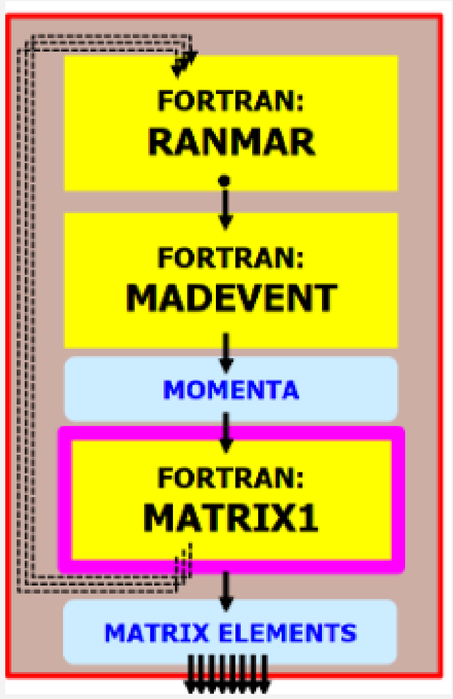
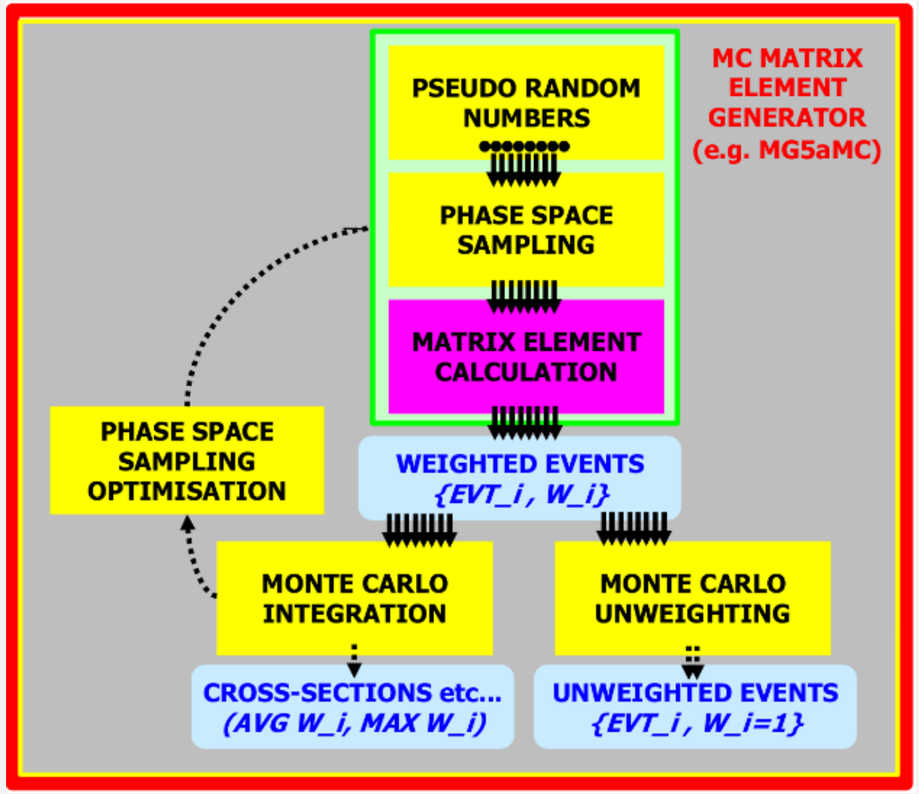
MADGRAPH_aMC@NLO CPU

What is MADGRAPH?:

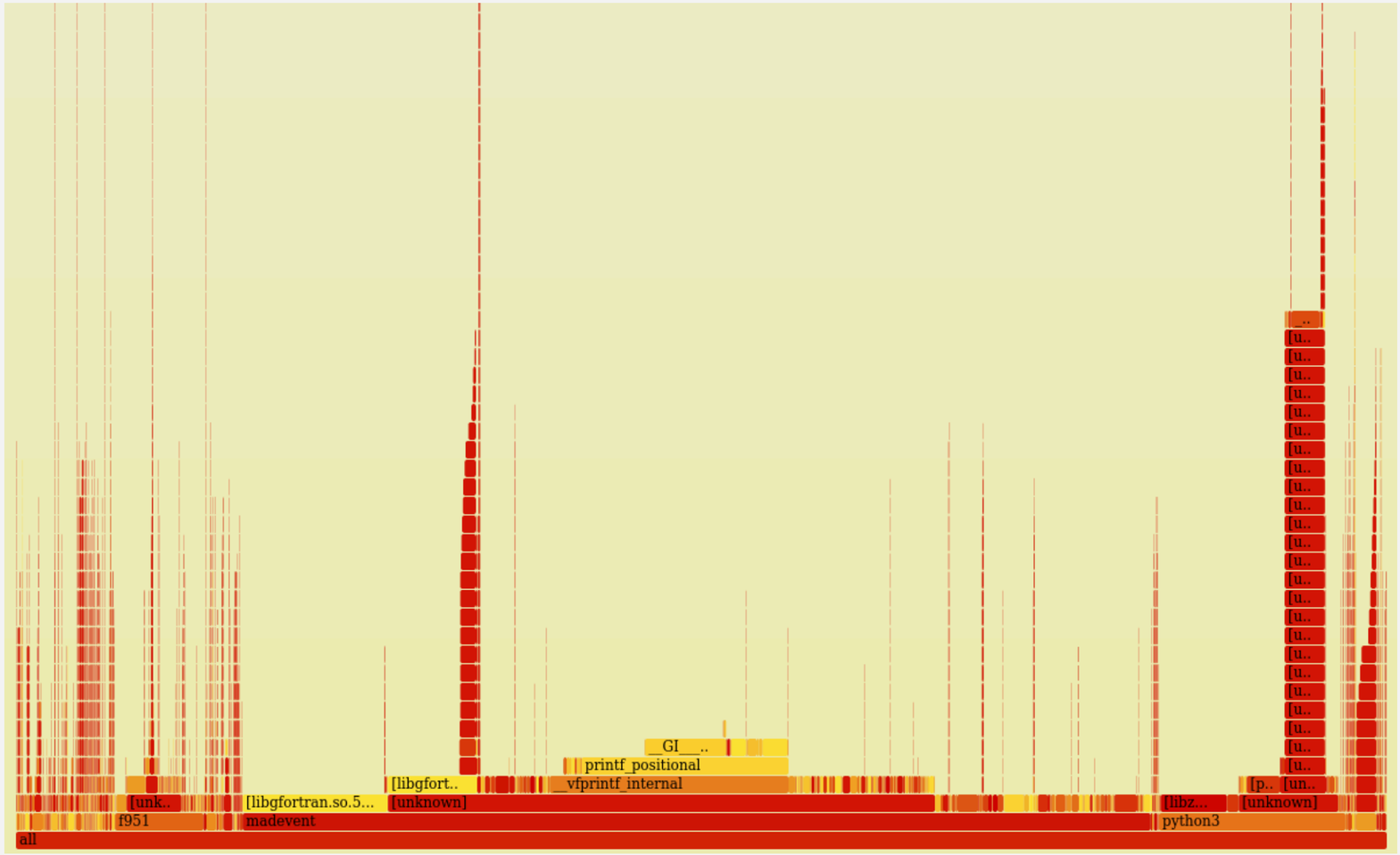
"MadGraph5_aMC@NLO is a framework that aims at providing all the elements necessary for SM and BSM phenomenology, such as the computations of cross sections, the generation of hard events and their matching with event generators. Processes can be simulated to LO accuracy for any user-defined Lagrangian, and the NLO accuracy in the case of QCD (Quantum Chromo Dynamics) corrections to SM processes. Matrix elements at the tree- and one-loop-level can also be obtained. "





MADGRAPH_aMC@NLO CPU

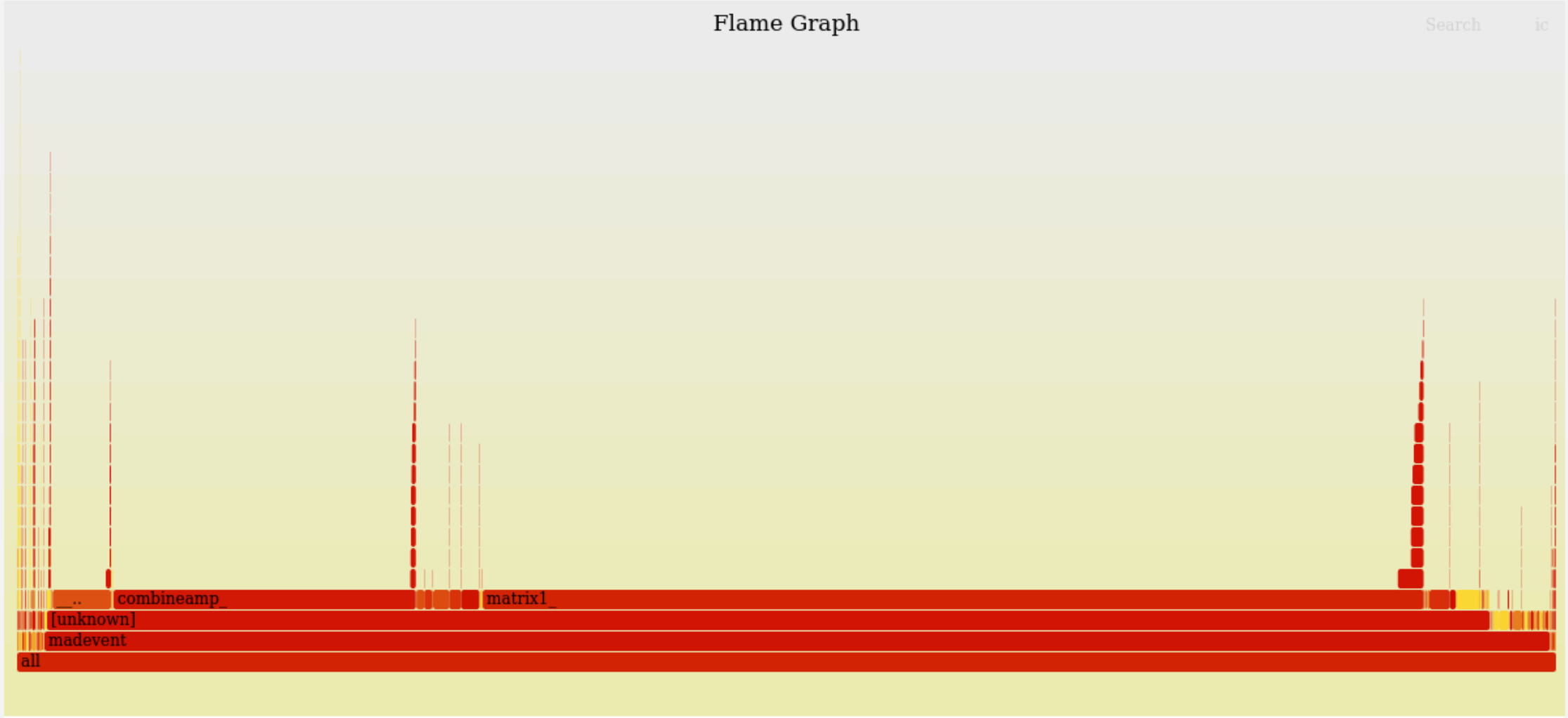
e+ e- > mu+ mu- **nevents = 204800** **Total executing time = 16 s**



Total_program (80%) = madevent (66%) + python3 (14%)
madevent (66%) = ME (40%) + other resources (26%)

MADGRAPH_aMC@NLO CPU

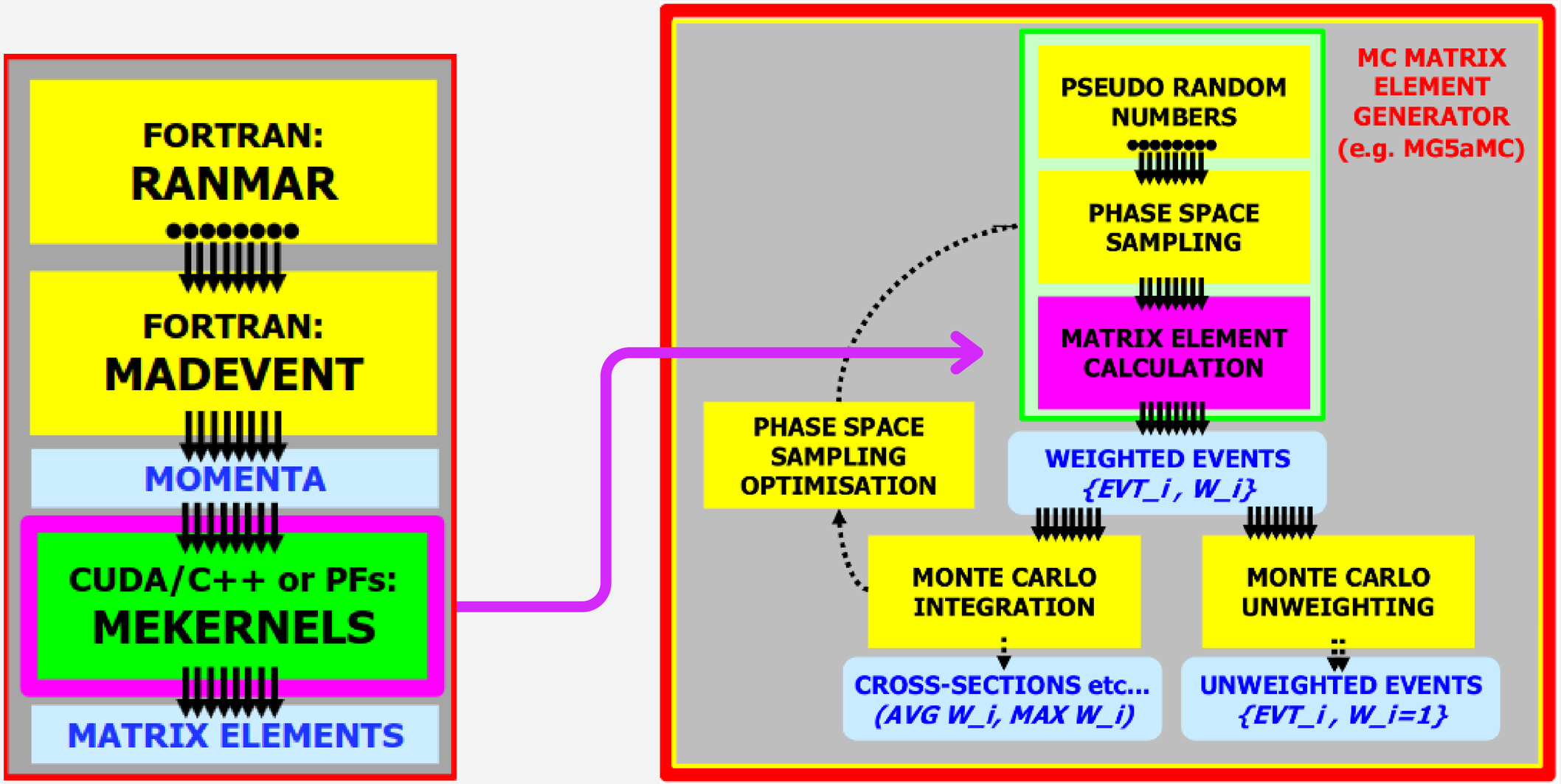
g g > t t~ g g g **nevents = 204800** **Total executing time = 32700 s = 9h**



madevent (97%) = ME (61%) + combineamp_ (20%) + other resources (16%)

5

MADGRAPH4GPU



Credits to: Madgraph5_aMC@NLO for GPUs group

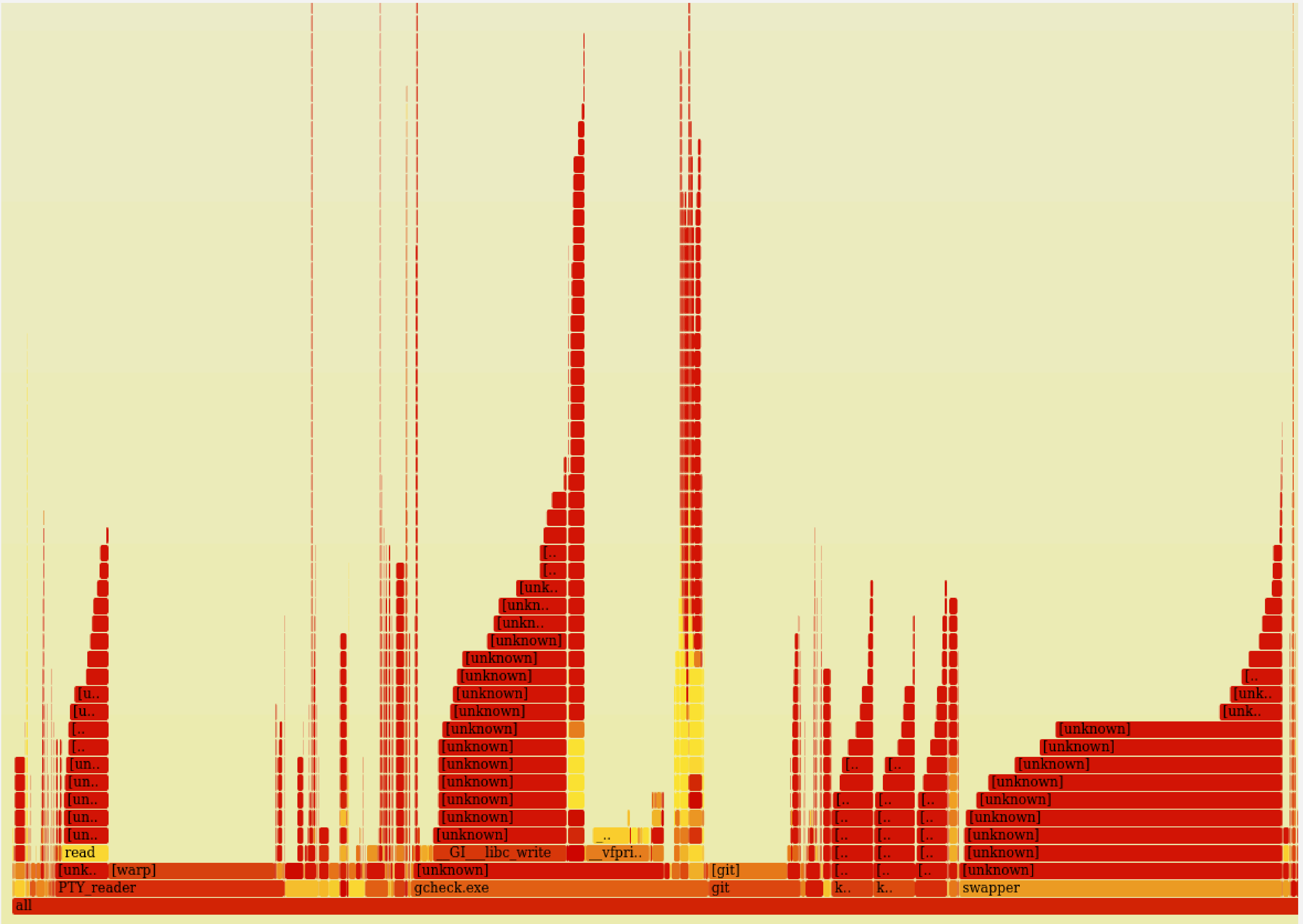
MADGRAPH4GPU

e+ e- > mu+ mu-

nevents = 204800

Total executing time = 3.8 s

Function Called



Events

Total_program (85%) =gcheck (27%) + Swapper (20%) + P_reader (18%) + Other_resources(20%)

gckeck (27%) = ME (24%) + other_CUDA_processes (3%)

Results CPU vs GPU

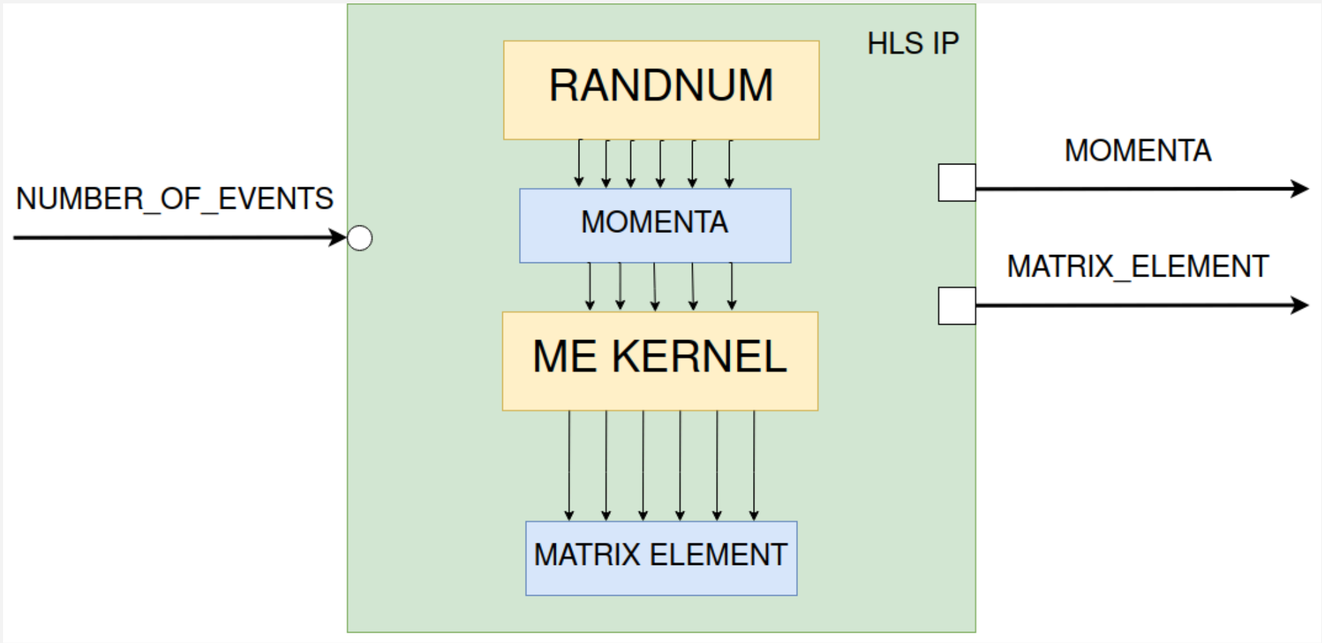
Process	N_events	t_CPU(s)	t_GPU(s)	SpeedUp
g g > t t~ g g g	204800	32700 (9 h)	260 (4 min)	125,7
g g > t t~ g g g	819200	155760 (43 h)	1046 (17 min)	148,9
g g > t t~ g g g	38000000	7,35E+06 (3 month) (extrapolation)	48895 (13 h)	150,3
e+ e- > mu+ mu-	204800	16.03+-0.07*	3,86+-0.01*	4,1
e+ e- > mu+ mu-	819200	70.05+-0.10*	15.29+-0.03*	4,5
e+ e- > mu+ mu-	6553600	512.1+-0.2* (8 min)	130.56+-0.03*	3,9

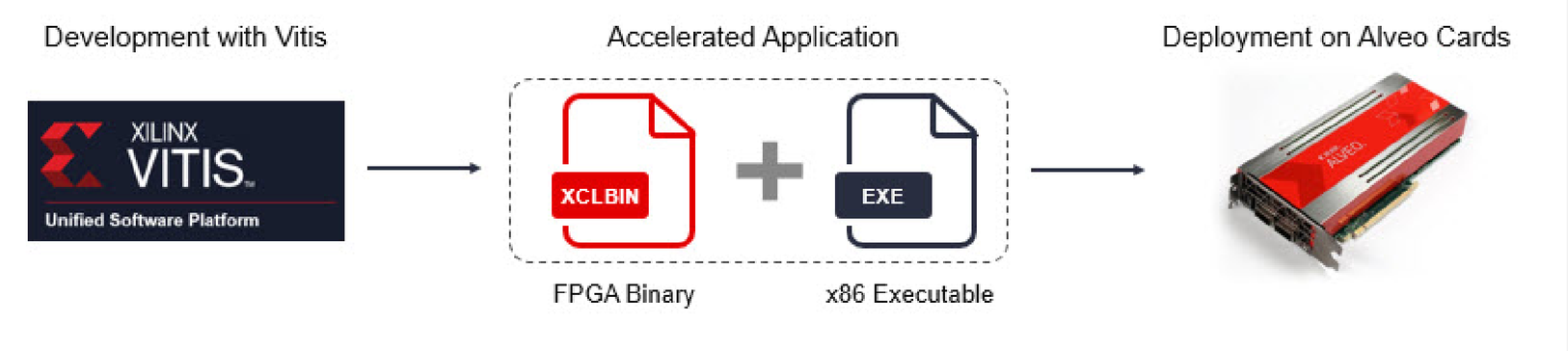
***RMS value**

MADGRAPH FPGA

Process: e- e+ > u- u+

- top -> check_sa.cpp (IN:NUMBER_OF_EVENTS, OUT: MOMENTA, OUT:MATRIX_ELEMENT)
  - Rambo -> Momenta
  - SigmaKin -> Matrix Element
- Rambo(Energy, masses, weight, masses_size)
  - Generate Random Numbers
    - Obtain Momenta
- SigmaKin
  - InitProc() -> SetIndependentCouplings
  - SetParameters & SetDependentcouplings
  - Calculate waveforms
  - Calculate matrix of the process
    - Obtain Matrix Element



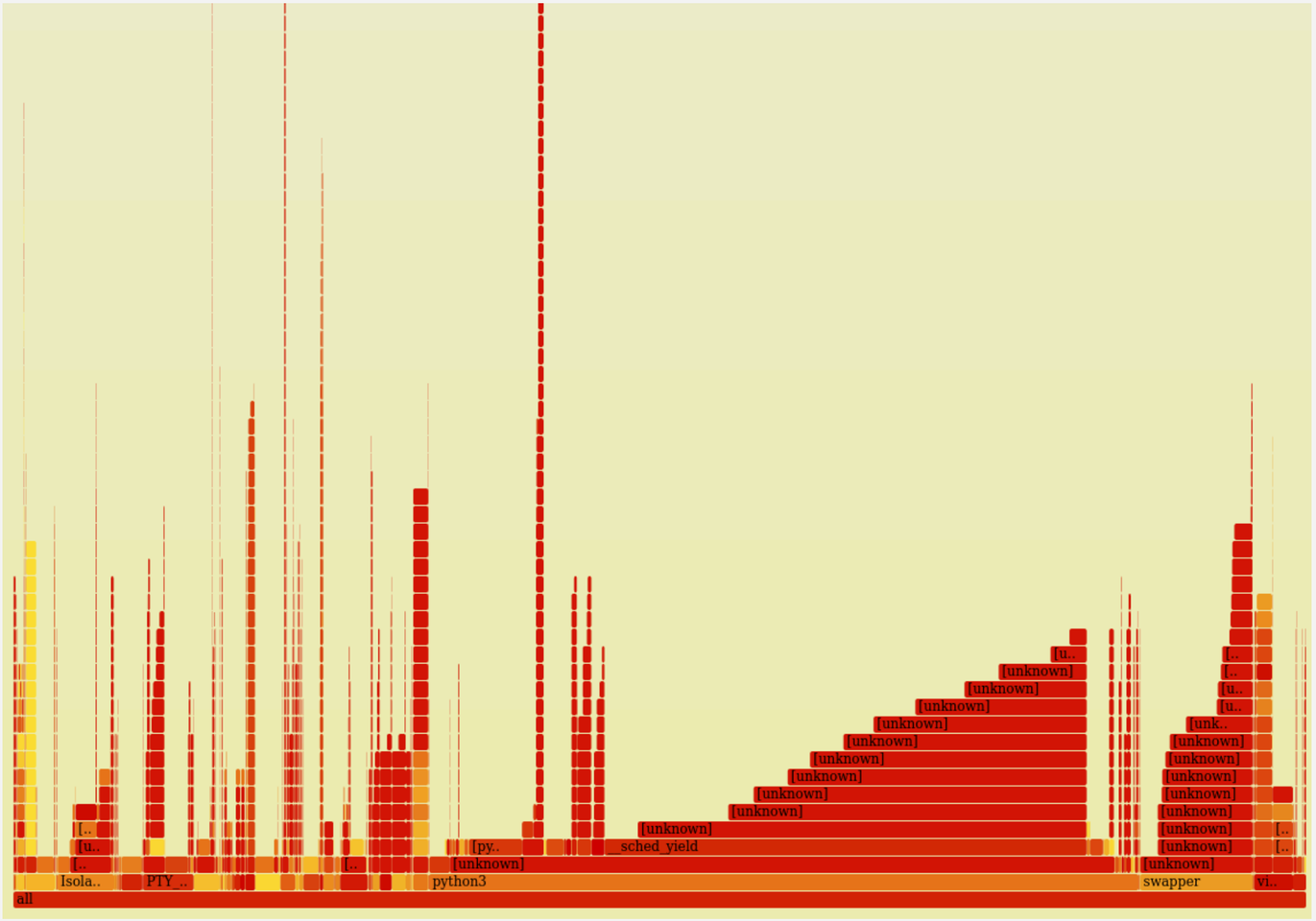


MADGRAPH FPGA

e+ e- > mu+ mu-

nevents = 204800

Total executing time = 0.48 s



Events

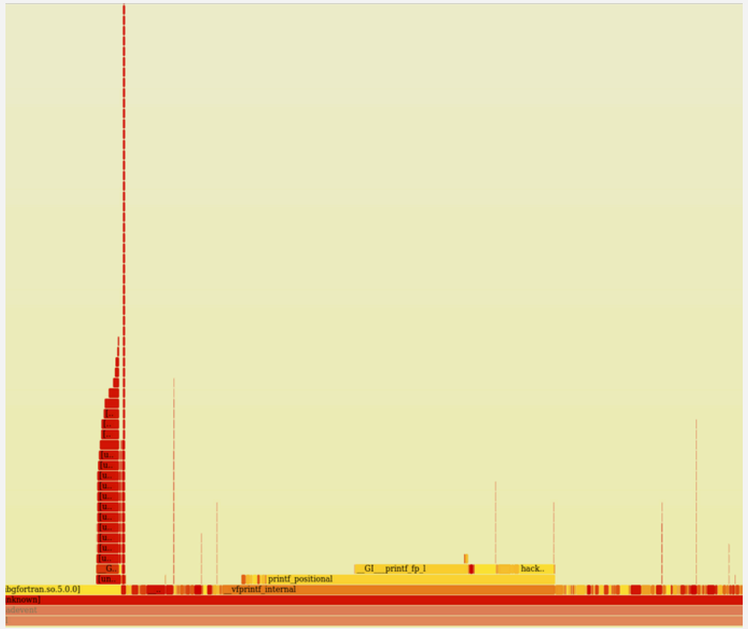
Total_program (81%) = Python3 (55%) + other resources (26%)

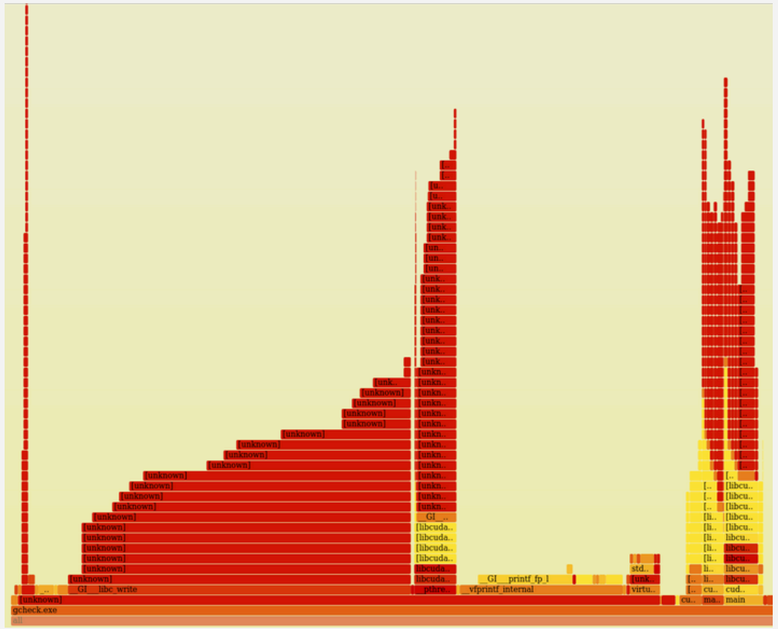
python3 (55%) = ME (18%) + Communication_FPGA_CPU (37%)

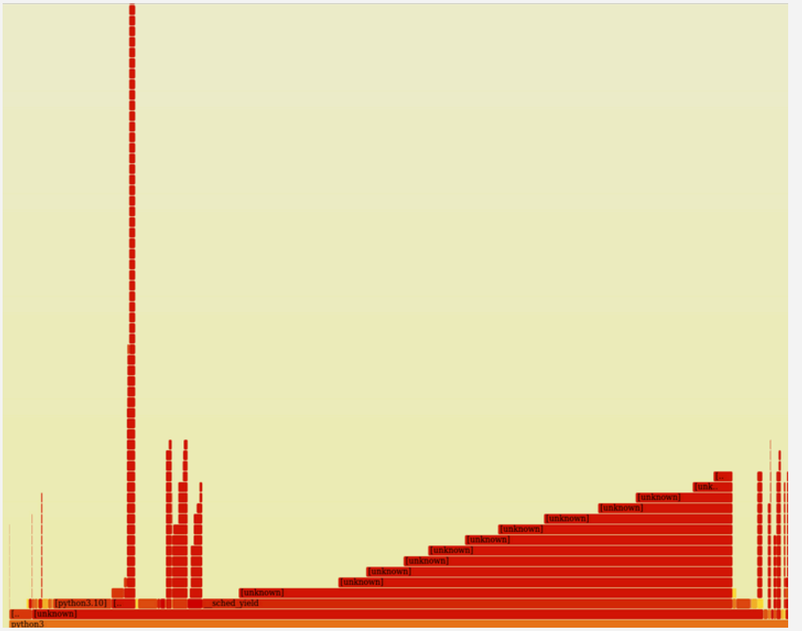
MADGRAPH FPGA

e+ e- > mu+ mu-

nevents = 204800







CPU

ME(40%)

GPU

ME(24%)

FPGA

ME(18%)

MADGRAPH FPGA

Process	BRAM	DSP	FF	LUT
me_calc	14	435	136833	81138

Frecuency (MHz)
100
Max = 137

Results CPU vs GPU vs FPGA

Process	N_events	t_CPU(s)	t_GPU(s)	t_FPGA(s)	Time(CPU/FPGA)	Time(GPU/FPGA)
e+ e- > mu+ mu-	204800	16.03+-0.07*	3,86+-0.01*	0.476+-0.004*	33,6	8,1
e+ e- > mu+ mu-	819200	70.05+-0.10*	15.29+-0.03*	1,324+-0.003*	52,9	11,5
e+ e- > mu+ mu-	6553600	512.1+-0.2* (8 min)	130.56+-0.03*	9,027+-0.001*	56,7	14,4

***RMS value**

Advantages and disadvantages of HLS for this application

- **Advantages:**
  - Increased Efficiency and Productivity
  - Better for prototyping
  - Reduce the development time
  - Enables developers to program FPGA in high-level languages
- **Disadvantages:**
  - Additional Translation Time
  - Slower Than coding RTL
  - Less control over memory resources

FUTURE IMPLEMENTATIONS

- Optimize the code for this case (e+e->u+u-)
- Create the code for a complex process
- Create the new version for all LO processes
- Study the implementation of BSM processes and NLO

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