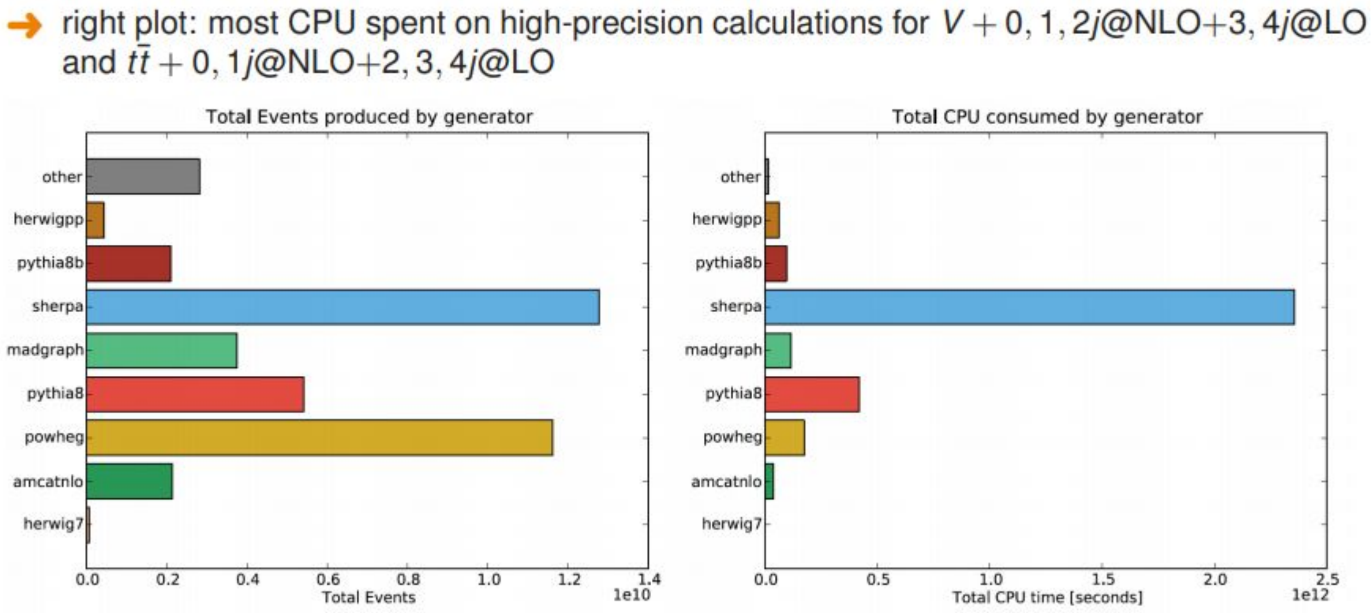
Sherpa W+Jet Profiling

Tim Martin, Warwick
June 19th 2020

Intro

- Noted in kickoff meeting that the largest CPU draw in ATLAS Event Generation comes from Sherpa SM processes. (CMS dominated by MadGraph, to a lesser extent)
- Investigate where this comes from, look for potential improvements.



➜ right plot: most CPU spent on high-precision calculations for $V + 0, 1, 2j$@NLO+3, 4j@LO and $t\bar{t} + 0, 1j$@NLO+2, 3, 4j@LO

Source CHRISTIAN GÜTSCHOW ECHEP Feb Workshop

Initial State

- Everything compiled out-the-box at O2
- Full ATLAS-representative W+Jets setup provided by Marek Schoenherr
  - **W+0,1,2j@NLO+3,4,5j@LO**
  - Including approximate virtual corrections and reweightings to different PDFs and scales
- Running 500 events EvGen
- Single-core
- Total time: 19,876 s (around 5h 30m)

Software and PC Details

- Local compilations of
  - Sherpa 2.2.8
  - OpenLoops 2.1.1
  - LHAPDF 6.2.3
  - HepMC 3.2.0
  - Intel(R) VTune(TM) Profiler 2020 (build 605129)

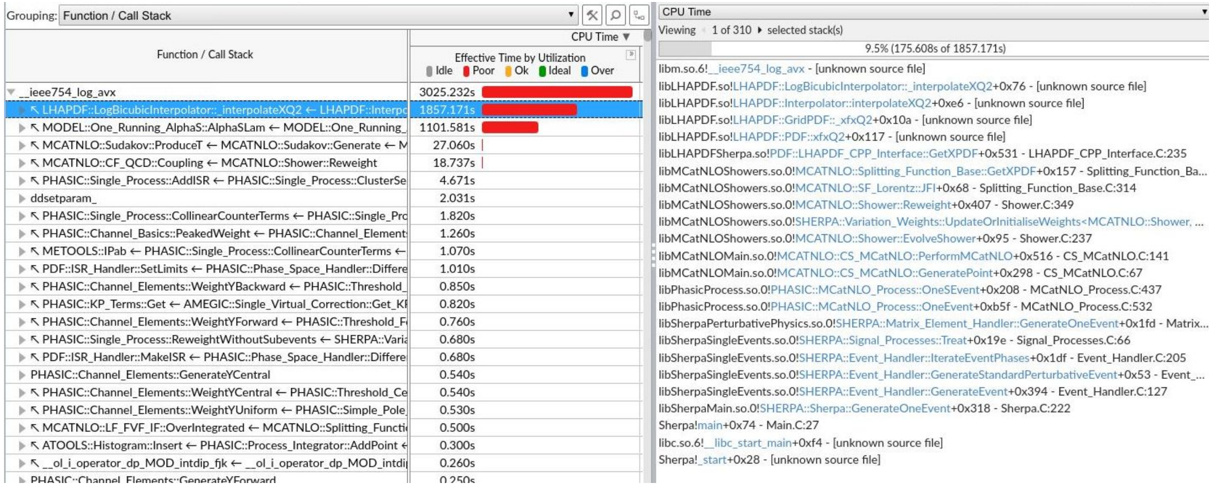
Profiling data collected by vtune running in userspace.
Visualisations of vtune database via flamegraph.

- Local software stack provides
  - gcc 5.5.0
  - Intel(R) icc 16.0.3 20160415
  - cmake 3.12.2
  - sqlite 3.24.0
  - root 6.1

```
CPU Details
vendor_id : GenuineIntel
cpu family      : 6
model           : 158
model name      : Intel(R) Core(TM) i7-7700 CPU @ 3.60GHz
stepping  : 9
microcode : 0xd6
cpu MHz         : 900.000
cache size      : 8192 KB
```

Vanilla CPU #1: log

- Unsurprisingly large call on transcendental functions. Two main callees
    - `-> LHAPDF::LogBicubicInterpolator::_interpolateXQ2 -> LHAPDF::Interpolator::interpolateXQ2 -> LHAPDF::GridPDF::_xfxQ2 -> LHAPDF::PDF::xfxQ2 -> PDF::LHAPDF_CPP_Interface::GetXPDF 1857.171s 0ms 0usec libLHAPDF.so LHAPDF::LogBicubicInterpolator::_interpolateXQ2(LHAPDF::KnotArray1F const&, double, unsigned long, double, unsigned long) const [Unknown] 0x453b0`
    - `-> MODEL::One_Running_AlphaS::AlphaSLam -> MODEL::One_Running_AlphaS::operator() 1101.581s  0ms  0usec libModelMain.so.0    MODEL::One_Running_AlphaS::AlphaSLam(double, int) Running_AlphaS.C     0x221b0`



Grouping: Function / Call Stack

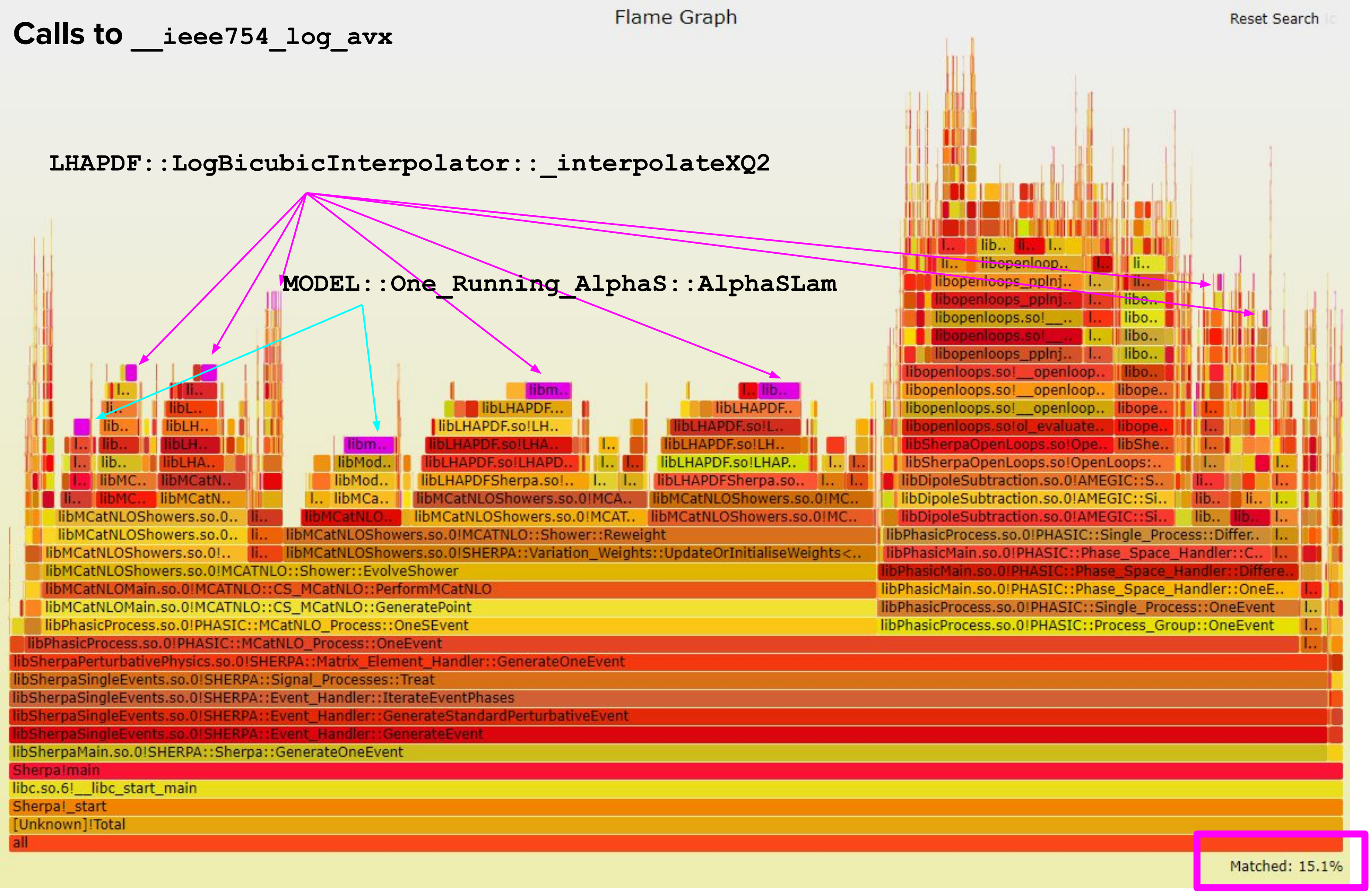
CPU Time: 1 of 310 selected stack(s)

Function / Call Stack	CPU Time ▼ Effective Time by Utilization ▮ Idle ▮ Poor ▮ Ok ▮ Ideal ▮ Over
▼ __ieee754_log_avx	3025.232s
▶ ↖ LHAPDF::LogBicubicInterpolator::_interpolateXQ2 ← LHAPDF::Interpo	1857.171s
▶ ↖ MODEL::One_Running_AlphaS::AlphaSLam ← MODEL::One_Running_	1101.581s
▶ ↖ MCATNLO::Sudakov::ProduceT ← MCATNLO::Sudakov::Generate ← M	27.060s
▶ ↖ MCATNLO::CF_QCD::Coupling ← MCATNLO::Shower::Reweight	18.737s
▶ ↖ PHASIC::Single_Process::AddISR ← PHASIC::Single_Process::ClusterSe	4.671s
▶ ddsetparam_	2.031s
▶ ↖ PHASIC::Single_Process::CollinearCounterTerms ← PHASIC::Single_Pro	1.820s
▶ ↖ PHASIC::Channel_Basics::PeakedWeight ← PHASIC::Channel_Element	1.260s
▶ ↖ METOOLS::IPab ← PHASIC::Single_Process::CollinearCounterTerms ←	1.070s
▶ ↖ PDF::ISR_Handler::SetLimits ← PHASIC::Phase_Space_Handler::Differe	1.010s
▶ ↖ PHASIC::Channel_Elements::WeightYBackward ← PHASIC::Threshold_	0.850s
▶ ↖ PHASIC::KP_Terms::Get ← AMEGIC::Single_Virtual_Correction::Get_KP	0.820s
▶ ↖ PHASIC::Channel_Elements::WeightYForward ← PHASIC::Threshold_F	0.760s
▶ ↖ PHASIC::Single_Process::ReweightWithoutSubevents ← SHERPA::Varia	0.680s
▶ ↖ PDF::ISR_Handler::MakeISR ← PHASIC::Phase_Space_Handler::Differe	0.680s
▶ PHASIC::Channel_Elements::GenerateYCentral	0.540s
▶ ↖ PHASIC::Channel_Elements::WeightYCentral ← PHASIC::Threshold_Ce	0.540s
▶ ↖ PHASIC::Channel_Elements::WeightYUniform ← PHASIC::Simple_Pole_	0.530s
▶ ↖ MCATNLO::LF_FVF_IF::OverIntegrated ← MCATNLO::Splitting_Functi	0.500s
▶ ↖ ATOOLS::Histogram::Insert ← PHASIC::Process_Integrator::AddPoint ←	0.300s
▶ ↖ __ol_i_operator_dp_MOD_intdip_fjk ← __ol_i_operator_dp_MOD_intdi	0.260s
▶ PHASIC::Channel_Elements::GenerateYForward	0.250s

9.5% (175.608s of 1857.171s)

```
libm.so.6!__ieee754_log_avx - [unknown source file]
libLHAPDF.so!LHAPDF::LogBicubicInterpolator::_interpolateXQ2+0x76 - [unknown source file]
libLHAPDF.so!LHAPDF::Interpolator::interpolateXQ2+0xe6 - [unknown source file]
libLHAPDF.so!LHAPDF::GridPDF::_xfxQ2+0x10a - [unknown source file]
libLHAPDF.so!LHAPDF::PDF::xfxQ2+0x117 - [unknown source file]
libLHAPDFSherpa.so!PDF::LHAPDF_CPP_Interface::GetXPDF+0x531 - LHAPDF_CPP_Interface.C:235
libMCatNLOShowers.so.0!MCATNLO::Splitting_Function_Base::GetXPDF+0x157 - Splitting_Function_Ba...
libMCatNLOShowers.so.0!MCATNLO::SF_Lorentz::JFI+0x68 - Splitting_Function_Base.C:314
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight+0x407 - Shower.C:349
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWeights<MCATNLO::Shower, ...
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower+0x95 - Shower.C:237
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO+0x516 - CS_MCatNLO.C:141
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint+0x298 - CS_MCatNLO.C:67
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent+0x208 - MCatNLO_Process.C:437
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0xb5f - MCatNLO_Process.C:532
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::GenerateOneEvent+0x1fd - Matrix...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x19e - Signal_Processes.C:66
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x1df - Event_Handler.C:205
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPerturbativeEvent+0x53 - Event_...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent+0x394 - Event_Handler.C:127
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent+0x318 - Sherpa.C:222
Sherpa!main+0x74 - Main.C:27
libc.so.6!__libc_start_main+0xf4 - [unknown source file]
Sherpa!_start+0x28 - [unknown source file]
```

Calls to `__ieee754_log_avx`

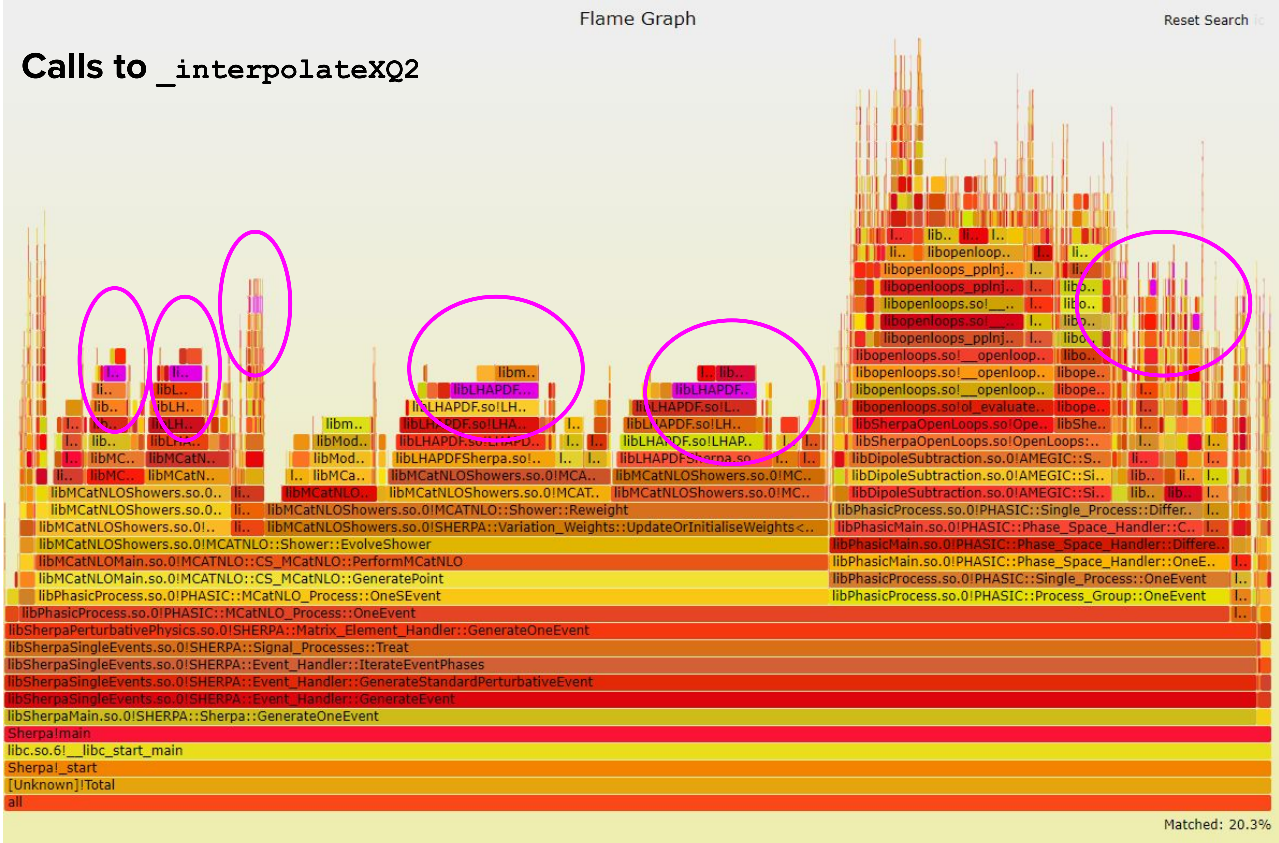


`LHAPDF::LogBicubicInterpolator::_interpolateXQ2`

`MODEL::One_Running_AlphaS::AlphaSLam`

Vanilla CPU #2: _interpolateXQ2

- As well as the time spent calling log, the function amasses a further 1,211 s

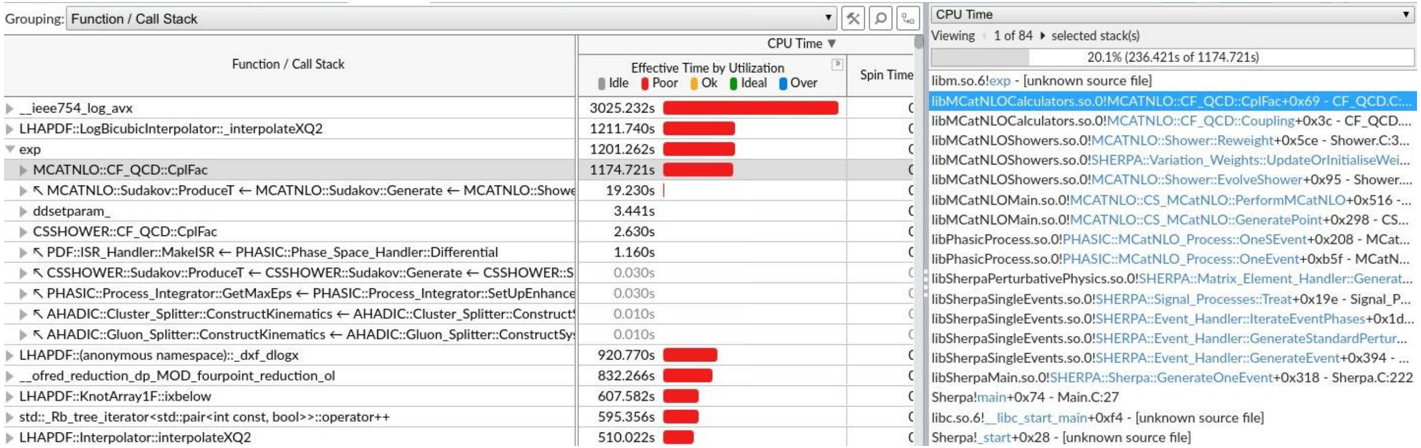


Calls to `_interpolateXQ2`

Flame Graph
Reset Search
Matched: 20.3%
all
[Unknown]!Total
Sherpa!_start
libc.so.6!__libc_start_main
Sherpa!main
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPerturbativeEvent
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::GenerateOneEvent
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWeights<..
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight
libMCatNLOShowers.so.0!MCAT..
libMCatNLOShowers.so.0!MCA..
libMCatNLOShowers.so.0!MC..
libLHAPDFSherpa.so!..
libLHAPDF.so!LHAPD..
libLHAPDF.so!LHA..
libLHAPDF.so!LH..
libLHAPDF..
libm..
libMCatNLOShowers.so.0..
libMCatNLOShowers.so.0!..
libMCatN..
libMC..
libMod..
libMCa..
libPhasicProcess.so.0!PHASIC::Process_Group::OneEvent
libPhasicProcess.so.0!PHASIC::Single_Process::OneEvent
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::OneE..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::Differe..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::C..
libPhasicProcess.so.0!PHASIC::Single_Process::Differ..
libDipoleSubtraction.so.0!AMEGIC::Si..
libDipoleSubtraction.so.0!AMEGIC::S..
libSherpaOpenLoops.so!OpenLoops::..
libSherpaOpenLoops.so!Ope..
libopenloops.so!ol_evaluate..
libopenloops.so!__openloop..
libopenloops_pplnj..
libopenloops.so!__..
libopenloop..
libope..
libShe..

Vanilla CPU #3: exp

- Another transcendental takes the third slot at 1,174 s
- `MCATNLO::CF_QCD::CplFac    1174.721s  0ms   0usec libMCatNLOCalculators.so.0`
  `MCATNLO::CF_QCD::CplFac(double const&) const    CF_QCD.C   0xb420`



Grouping: Function / Call Stack

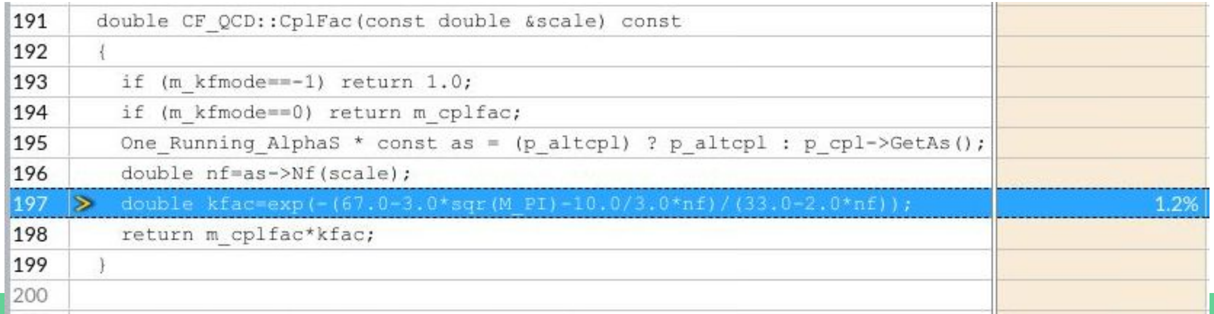
Function / Call Stack	CPU Time ▼ Effective Time by Utilization ▮ Idle ▮ Poor ▮ Ok ▮ Ideal ▮ Over	Spin Time
▶ __ieee754_log_avx	3025.232s	0
▶ LHAPDF::LogBicubicInterpolator::_interpolateXQ2	1211.740s	0
▼ exp	1201.262s	0
▶ MCATNLO::CF_QCD::CplFac	1174.721s	0
▶ ↖ MCATNLO::Sudakov::ProduceT ← MCATNLO::Sudakov::Generate ← MCATNLO::Showe	19.230s	0
▶ ddsetparam_	3.441s	0
▶ CSSHOWER::CF_QCD::CplFac	2.630s	0
▶ ↖ PDF::ISR_Handler::MakeISR ← PHASIC::Phase_Space_Handler::Differential	1.160s	0
▶ ↖ CSSHOWER::Sudakov::ProduceT ← CSSHOWER::Sudakov::Generate ← CSSHOWER::S	0.030s	0
▶ ↖ PHASIC::Process_Integrator::GetMaxEps ← PHASIC::Process_Integrator::SetUpEnhance	0.030s	0
▶ ↖ AHADIC::Cluster_Splitter::ConstructKinematics ← AHADIC::Cluster_Splitter::Construct	0.010s	0
▶ ↖ AHADIC::Gluon_Splitter::ConstructKinematics ← AHADIC::Gluon_Splitter::ConstructSy	0.010s	0
▶ LHAPDF::(anonymous namespace)::_dxf_dlogx	920.770s	0
▶ __ofred_reduction_dp_MOD_fourpoint_reduction_ol	832.266s	0
▶ LHAPDF::KnotArray1F::ixbelow	607.582s	0
▶ std::_Rb_tree_iterator<std::pair<int const, bool>>::operator++	595.356s	0
▶ LHAPDF::Interpolator::interpolateXQ2	510.022s	0

CPU Time ▼

Viewing ◂ 1 of 84 ▸ selected stack(s)

20.1% (236.421s of 1174.721s)

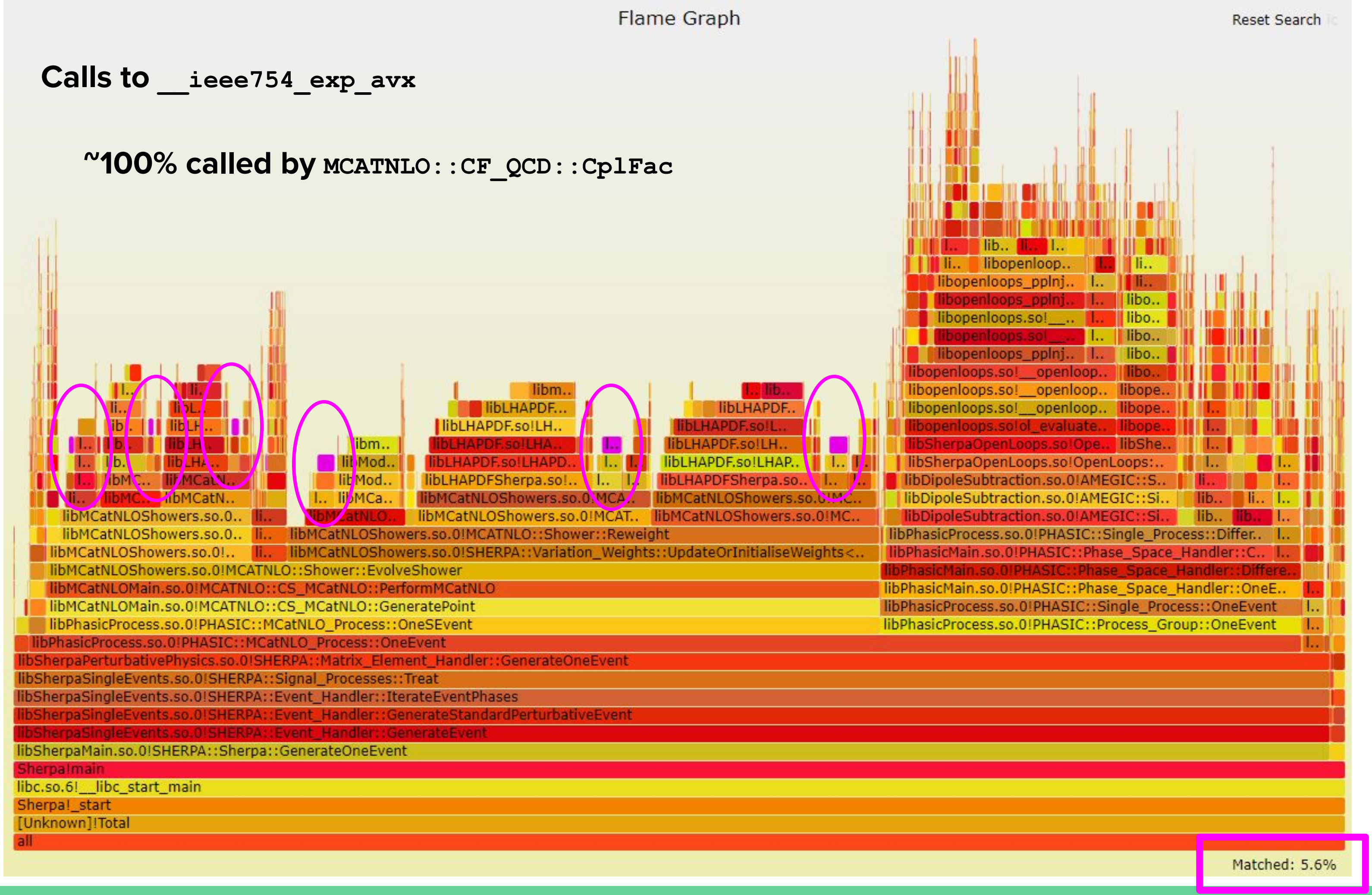
```
libm.so.6!exp - [unknown source file]
libMCatNLOCalculators.so.0!MCATNLO::CF_QCD::CplFac+0x69 - CF_QCD.C:...
libMCatNLOCalculators.so.0!MCATNLO::CF_QCD::Coupling+0x3c - CF_QCD....
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight+0x5ce - Shower.C:3...
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWei...
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower+0x95 - Shower....
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO+0x516 -...
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint+0x298 - CS...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent+0x208 - MCat...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0xb5f - MCatN...
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::Generat...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x19e - Signal_P...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x1d...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPertur...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent+0x394 - ...
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent+0x318 - Sherpa.C:222
Sherpa!main+0x74 - Main.C:27
libc.so.6!__libc_start_main+0xf4 - [unknown source file]
Sherpa!_start+0x28 - [unknown source file]
```



```
double CF_QCD::CplFac(const double &scale) const
{
  if (m_kfmode==-1) return 1.0;
  if (m_kfmode==0) return m_cplfac;
  One_Running_AlphaS * const as = (p_altcpl) ? p_altcpl : p_cpl->GetAs();
  double nf=as->Nf(scale);
> double kfac=exp(-(67.0-3.0*sqr(M_PI)-10.0/3.0*nf)/(33.0-2.0*nf));     1.2%
  return m_cplfac*kfac;
}
```

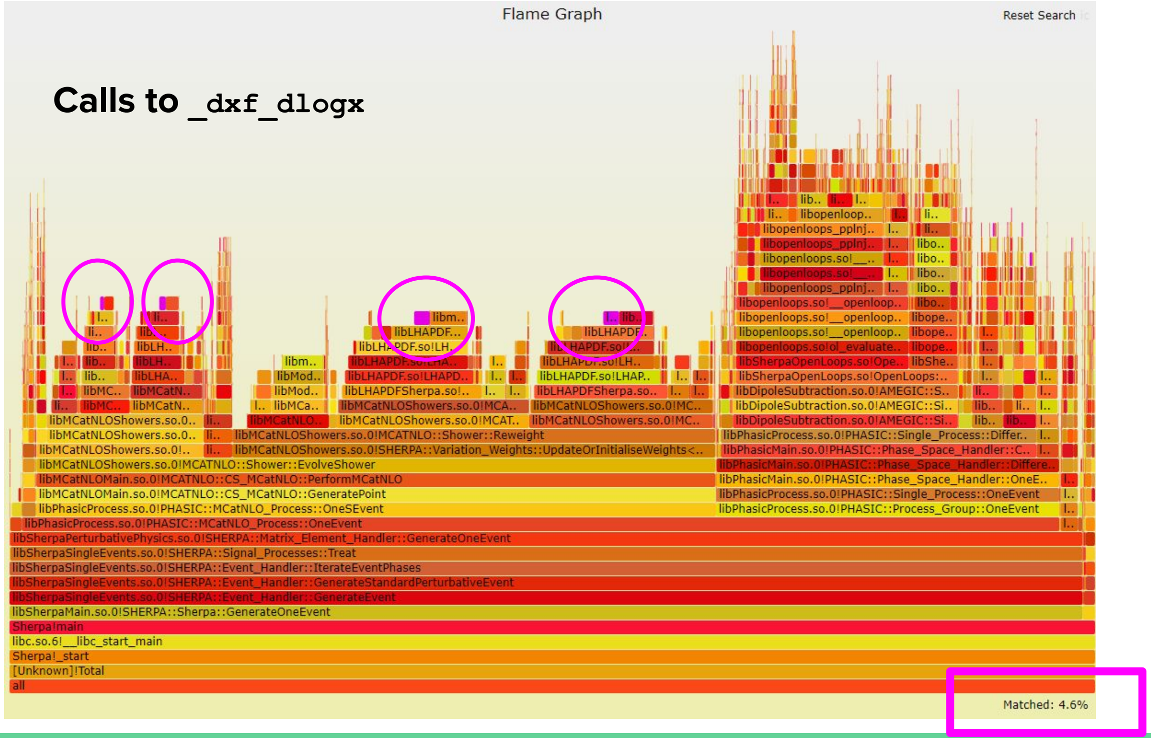
Calls to `__ieee754_exp_avx`

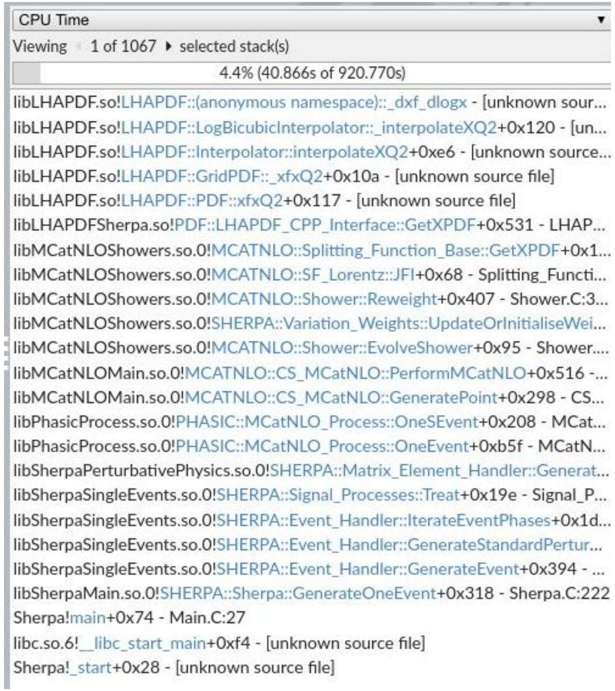
~100% called by `MCATNLO::CF_QCD::CplFac`


Flame Graph
Reset Search
libopenloop..
libopenloops_pplnj..
libopenloops.so!__..
libopenloops.so!__openloop..
libopenloops.so!ol_evaluate..
libSherpaOpenLoops.so!Ope..
libSherpaOpenLoops.so!OpenLoops::..
libDipoleSubtraction.so.0!AMEGIC::S..
libDipoleSubtraction.so.0!AMEGIC::Si..
libPhasicProcess.so.0!PHASIC::Single_Process::Differ..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::C..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::Differe..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::OneE..
libPhasicProcess.so.0!PHASIC::Single_Process::OneEvent
libPhasicProcess.so.0!PHASIC::Process_Group::OneEvent
libm..
libLHAPDF...
libLHAPDF.so!LH..
libLHAPDF.so!LHA..
libLHAPDF.so!LHAPD..
libLHAPDF.so!LHAP..
libLHAPDFSherpa.so!..
libMod..
libMCa..
libMCatNLO..
libMCatNLOShowers.so.0!MCAT..
libMCatNLOShowers.so.0!MC..
libMCatNLOShowers.so.0..
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWeights<..
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::GenerateOneEvent
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPerturbativeEvent
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent
Sherpa!main
libc.so.6!__libc_start_main
Sherpa!_start
[Unknown]!Total
all
Matched: 5.6%

Vanilla CPU #4: _dxf_dlogx

- Like #1, #4 is a child of #2 `_interpolateXQ2`
- LHAPDF::LogBicubicInterpolator::_interpolateXQ2 -> LHAPDF::Interpolator::interpolateXQ2 -> LHAPDF::GridPDF::_xfxQ2 -> LHAPDF::PDF::xfxQ2 -> PDF::LHAPDF_CPP_Interface::GetXPDF 920.770s





CPU Time ▾

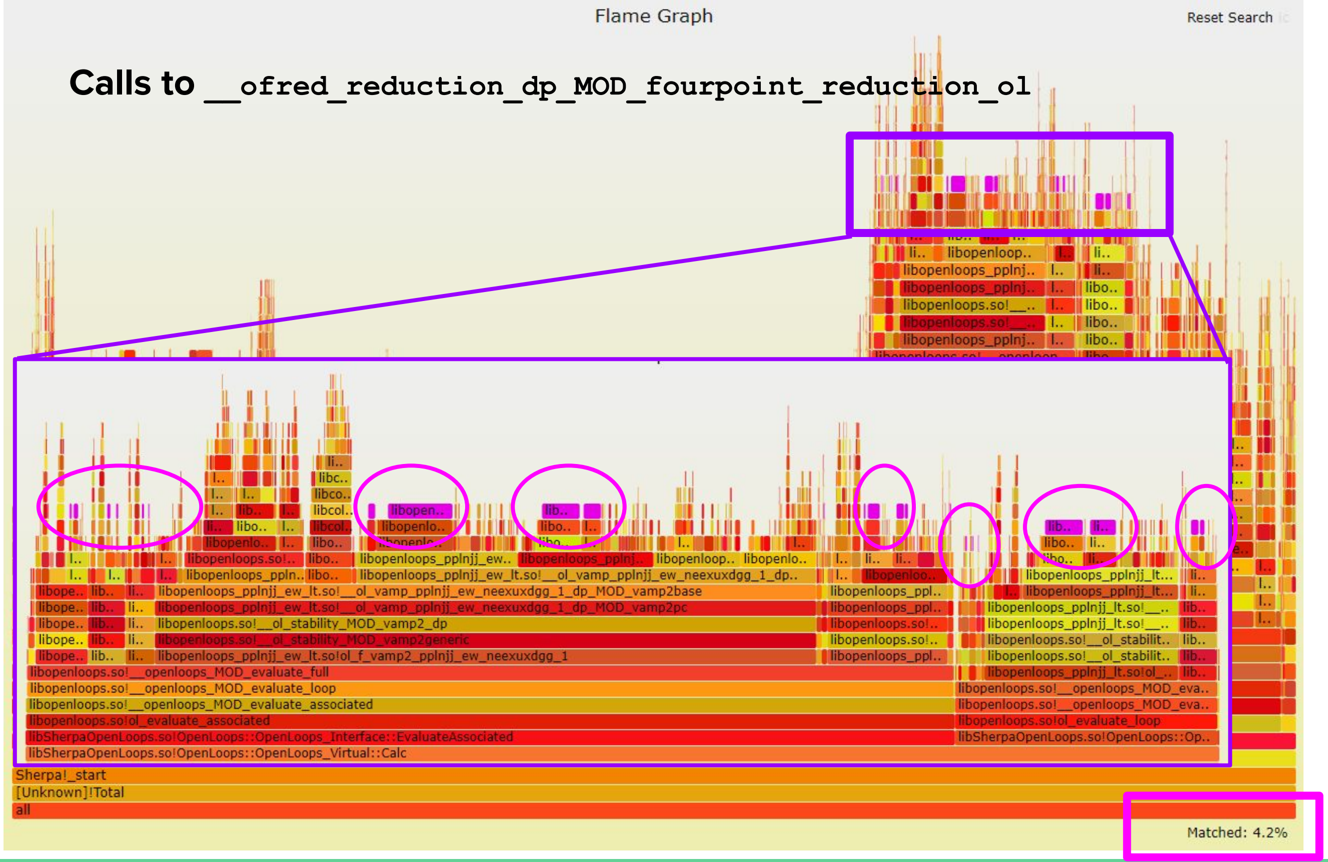
Viewing 1 of 1067 ▸ selected stack(s)

4.4% (40.866s of 920.770s)

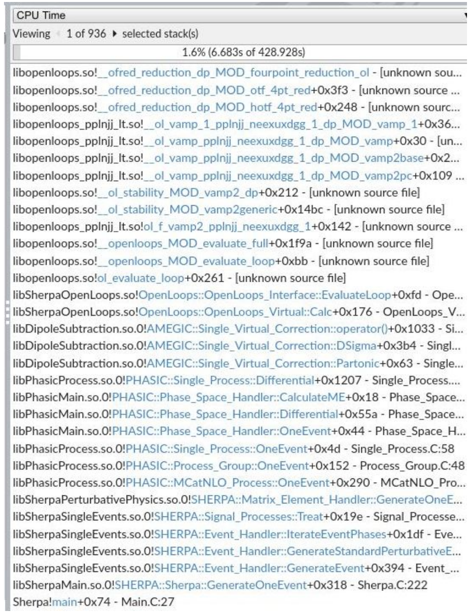
libLHAPDF.so!LHAPDF::(anonymous namespace)::_dxf_dlogx - [unknown sour...
libLHAPDF.so!LHAPDF::LogBicubicInterpolator::_interpolateXQ2+0x120 - [un...
libLHAPDF.so!LHAPDF::Interpolator::interpolateXQ2+0xe6 - [unknown source...
libLHAPDF.so!LHAPDF::GridPDF::_xfxQ2+0x10a - [unknown source file]
libLHAPDF.so!LHAPDF::PDF::xfxQ2+0x117 - [unknown source file]
libLHAPDFSherpa.so!PDF::LHAPDF_CPP_Interface::GetXPDF+0x531 - LHAP...
libMCatNLOShowers.so.0!MCATNLO::Splitting_Function_Base::GetXPDF+0x1...
libMCatNLOShowers.so.0!MCATNLO::SF_Lorentz::JFI+0x68 - Splitting_Functi...
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight+0x407 - Shower.C:3...
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWei...
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower+0x95 - Shower....
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO+0x516 -...
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint+0x298 - CS...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent+0x208 - MCat...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0xb5f - MCatN...
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::Generat...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x19e - Signal_P...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x1d...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPertur...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent+0x394 - ...
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent+0x318 - Sherpa.C:222
Sherpa!main+0x74 - Main.C:27
libc.so.6!__libc_start_main+0xf4 - [unknown source file]
Sherpa!_start+0x28 - [unknown source file]

Vanilla CPU #5: ofred_reduction_dp_MOD_fourpoint_reduction_ol

- Top single CPU calling coming from Openloops at 832 s



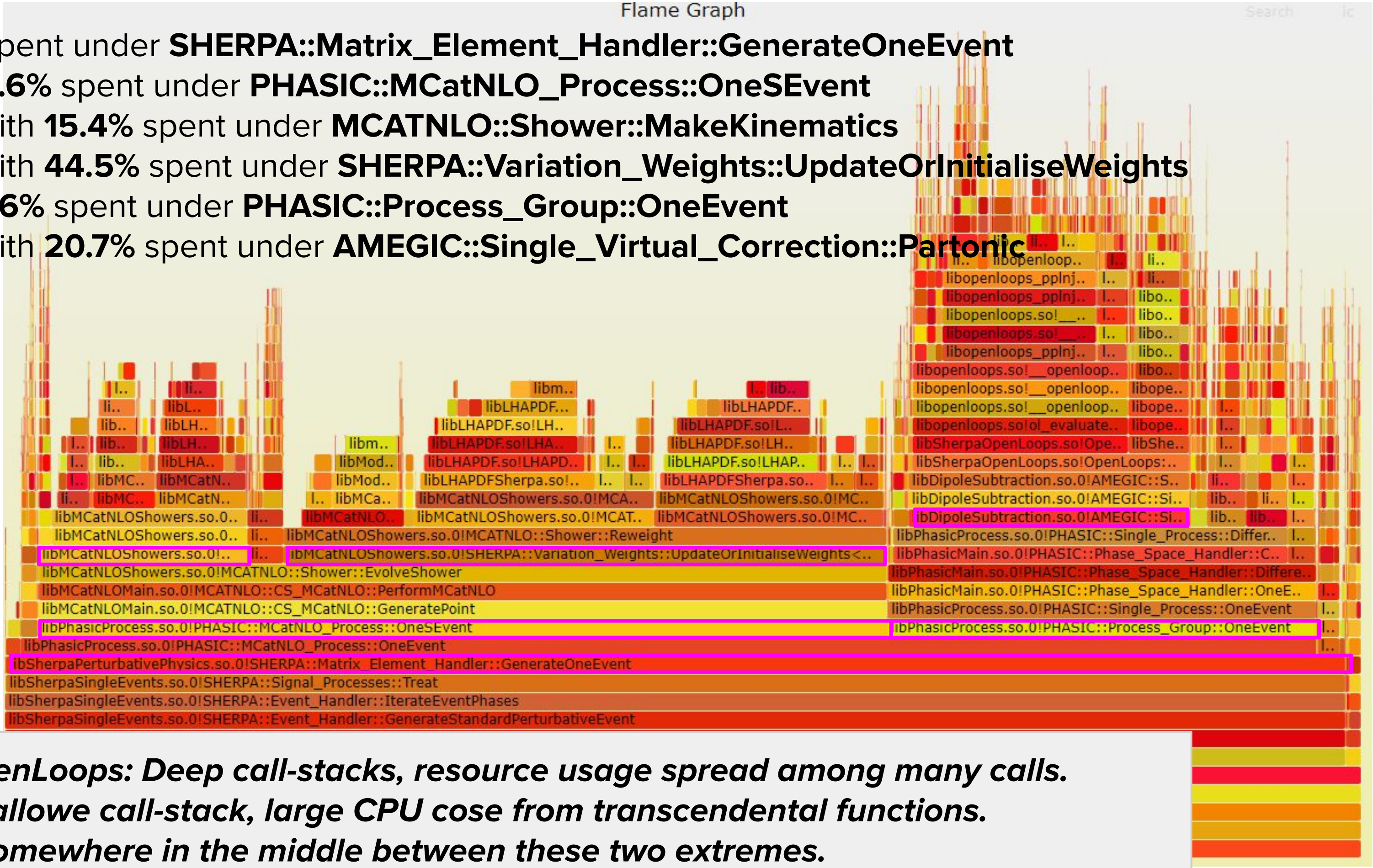
Calls to __ofred_reduction_dp_MOD_fourpoint_reduction_ol



```
CPU Time
Viewing  1 of 936 ▸ selected stack(s)
1.6% (6.683s of 428.928s)
libopenloops.so!__ofred_reduction_dp_MOD_fourpoint_reduction_ol - [unknown sou...
libopenloops.so!__ofred_reduction_dp_MOD_otf_4pt_red+0x3f3 - [unknown source ...
libopenloops.so!__ofred_reduction_dp_MOD_hotf_4pt_red+0x248 - [unknown sourc...
libopenloops_pplnjj_lt.so!__ol_vamp_1_pplnjj_neexuxdgg_1_dp_MOD_vamp_1+0x36...
libopenloops_pplnjj_lt.so!__ol_vamp_pplnjj_neexuxdgg_1_dp_MOD_vamp+0x30 - [un...
libopenloops_pplnjj_lt.so!__ol_vamp_pplnjj_neexuxdgg_1_dp_MOD_vamp2base+0x2...
libopenloops_pplnjj_lt.so!__ol_vamp_pplnjj_neexuxdgg_1_dp_MOD_vamp2pc+0x109 ...
libopenloops.so!__ol_stability_MOD_vamp2_dp+0x212 - [unknown source file]
libopenloops.so!__ol_stability_MOD_vamp2generic+0x14bc - [unknown source file]
libopenloops_pplnjj_lt.so!ol_f_vamp2_pplnjj_neexuxdgg_1+0x142 - [unknown source ...
libopenloops.so!__openloops_MOD_evaluate_full+0x1f9a - [unknown source file]
libopenloops.so!__openloops_MOD_evaluate_loop+0xbb - [unknown source file]
libopenloops.so!ol_evaluate_loop+0x261 - [unknown source file]
libSherpaOpenLoops.so!OpenLoops::OpenLoops_Interface::EvaluateLoop+0xfd - Ope...
libSherpaOpenLoops.so!OpenLoops::OpenLoops_Virtual::Calc+0x176 - OpenLoops_V...
libDipoleSubtraction.so.0!AMEGIC::Single_Virtual_Correction::operator()+0x1033 - Si...
libDipoleSubtraction.so.0!AMEGIC::Single_Virtual_Correction::DSigma+0x3b4 - Singl...
libDipoleSubtraction.so.0!AMEGIC::Single_Virtual_Correction::Partonic+0x63 - Single...
libPhasicProcess.so.0!PHASIC::Single_Process::Differential+0x1207 - Single_Process....
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::CalculateME+0x18 - Phase_Space...
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::Differential+0x55a - Phase_Space...
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::OneEvent+0x44 - Phase_Space_H...
libPhasicProcess.so.0!PHASIC::Single_Process::OneEvent+0x4d - Single_Process.C:58
libPhasicProcess.so.0!PHASIC::Process_Group::OneEvent+0x152 - Process_Group.C:48
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0x290 - MCatNLO_Pro...
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::GenerateOneE...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x19e - Signal_Processe...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x1df - Eve...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPerturbativeE...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent+0x394 - Event_...
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent+0x318 - Sherpa.C:222
Sherpa!main+0x74 - Main.C:27
```

Vanilla O2 Summary

1. **98%** of time spent under **SHERPA::Matrix_Element_Handler::GenerateOneEvent**
   a. With **62.6%** spent under **PHASIC::MCatNLO_Process::OneSEvent**
      i. With **15.4%** spent under **MCATNLO::Shower::MakeKinematics**
      ii. With **44.5%** spent under **SHERPA::Variation_Weights::UpdateOrInitialiseWeights**
   b. With **31.6%** spent under **PHASIC::Process_Group::OneEvent**
      i. With **20.7%** spent under **AMEGIC::Single_Virtual_Correction::Partonic**



- ***AMEGIC, OpenLoops: Deep call-stacks, resource usage spread among many calls.***
- ***LHAPDF: Shallowe call-stack, large CPU cose from transcendental functions.***
- ***MCatNLO: Somewhere in the middle between these two extremes.***

Compile Time Optimisations

- Multiple easy **“slot in”** optimisation strategies tried.
    - **Memory allocation**: preload Google’s TCMALLOC
    - **Optimisation** level: O2 vs. O3
    - Beyond O3: **Minimum architecture** (msse4.2) and **unsafe maths** optimisations
    - **Link Time Optimisation**
    - Fully **static** single-process builds (**not managed successfully…**)
    - Use of Intel icc compiler.
        - O3, minimum architecture and unsafe maths flags with icc
- Optimisations were tried only on Sherpa and on Sherpa+LHAPDF. In some cases this resulted in a strange regression.
- TCMALLOC and VTune did not play nice.
- Working set of icc flags usable with both LHAPDF and Sherpa took some iterations.
- Have not checked so far if physics were impacted by unsafe maths.
- ***See backup slides for full details.***

Optimisation Timings

Optimisation	On Sherpa	On Sherpa+LHAPDF
None (O2)	19,876 s	N/A
Memory Allocation	19,505 s (-2%)	~83,463 s (!)
O3	19,506 s (-2%)	20,280 s (+2%)
Architecture & Unsafe Maths	20,183 s (+2%)	~82,785 s (!)
Link Time Optimisation	20,371 s (+2%)	~80,935 s (!)
Intel compiler		**18,122 s (-9%)**
Intel compiler + O3, Arch, Maths		18,598 s (-6%)

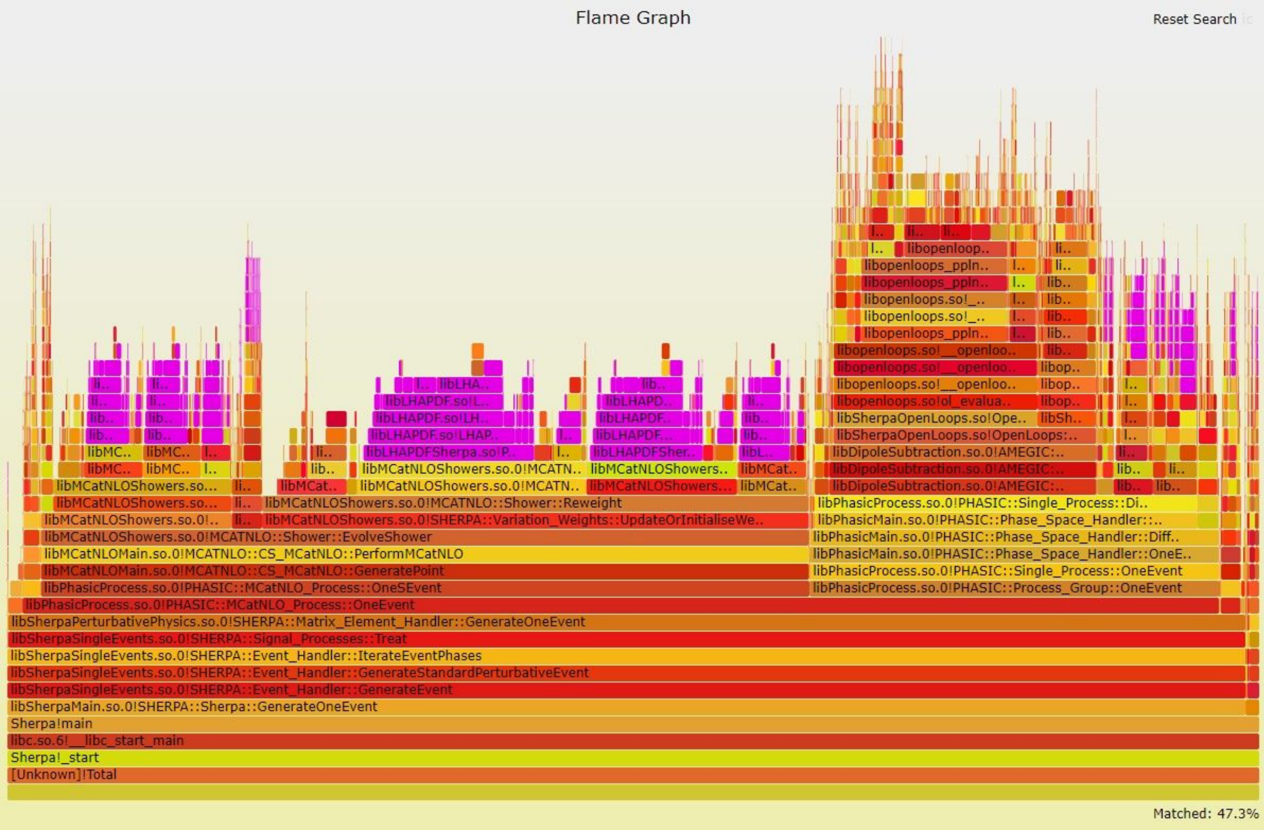
Intel savings look to come primarily through faster maths. C.f.

```
(gcc) __ieee754_log_avx = 3,025 s
(icc) __libm_log_l9 = 956 s
```

See also Manuel's slides from yesterday's ECHEP Reco meeting. Vectorisation can save much more.

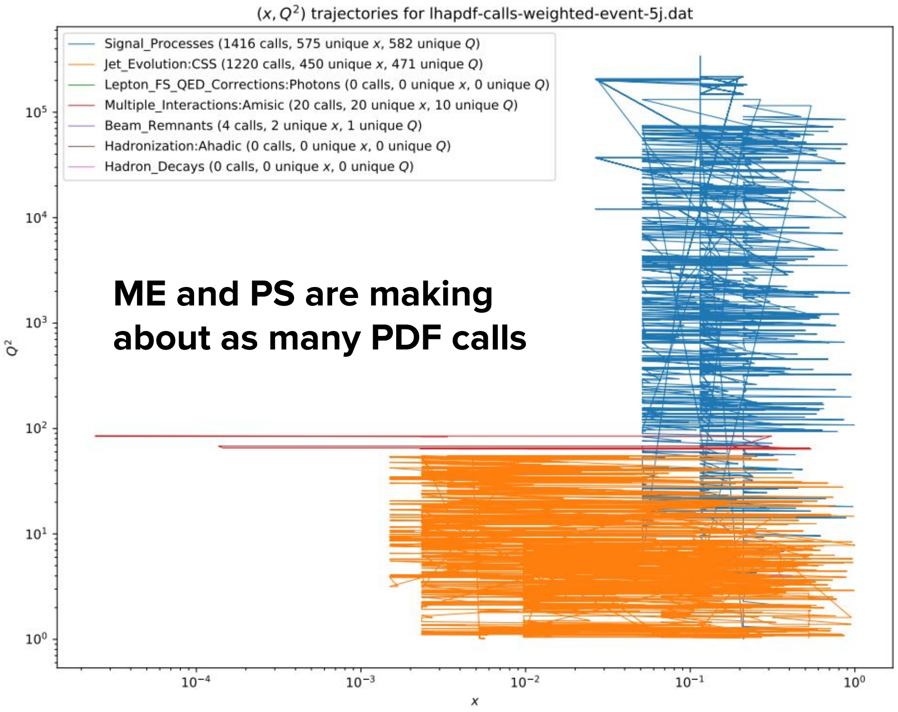
LHAPDF Load

- May have noted, a lot of the areas noted so far are actually calls into the HEPMC library.
- Integrated, it sums to **47.3%** of all time.

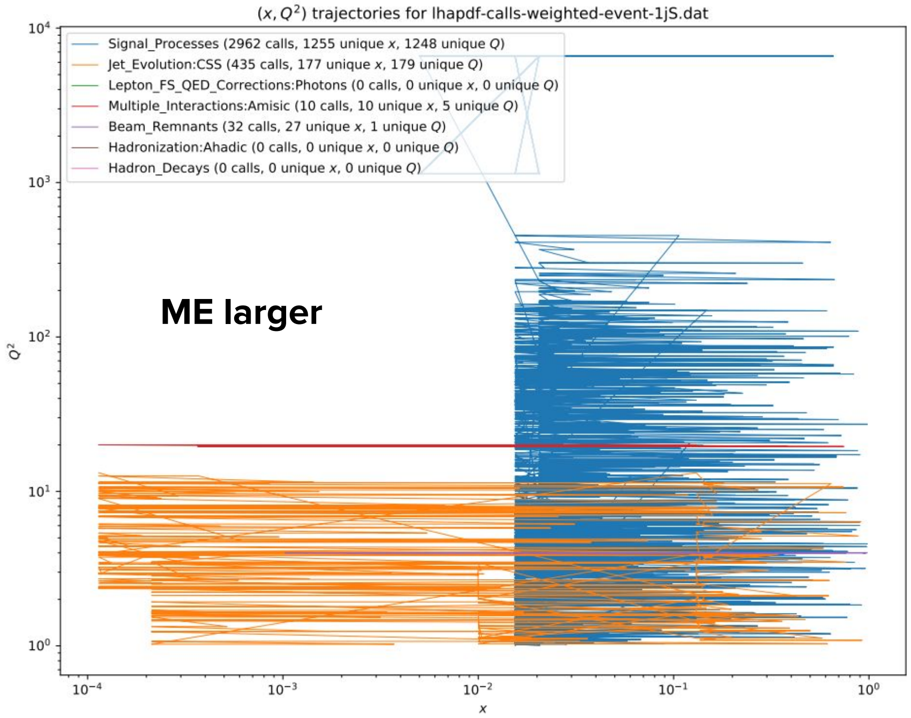


Investigation into PDF Evaluation Calls

- Single event dumps of calls by Sherpa produced by Marek
  - <flavour>,<x>,<Q2> for some different types of events (pp->W+0j S/H, 1j S/H, 5j LO)
- Visualised by Andy



ME and PS are making about as many PDF calls



ME larger

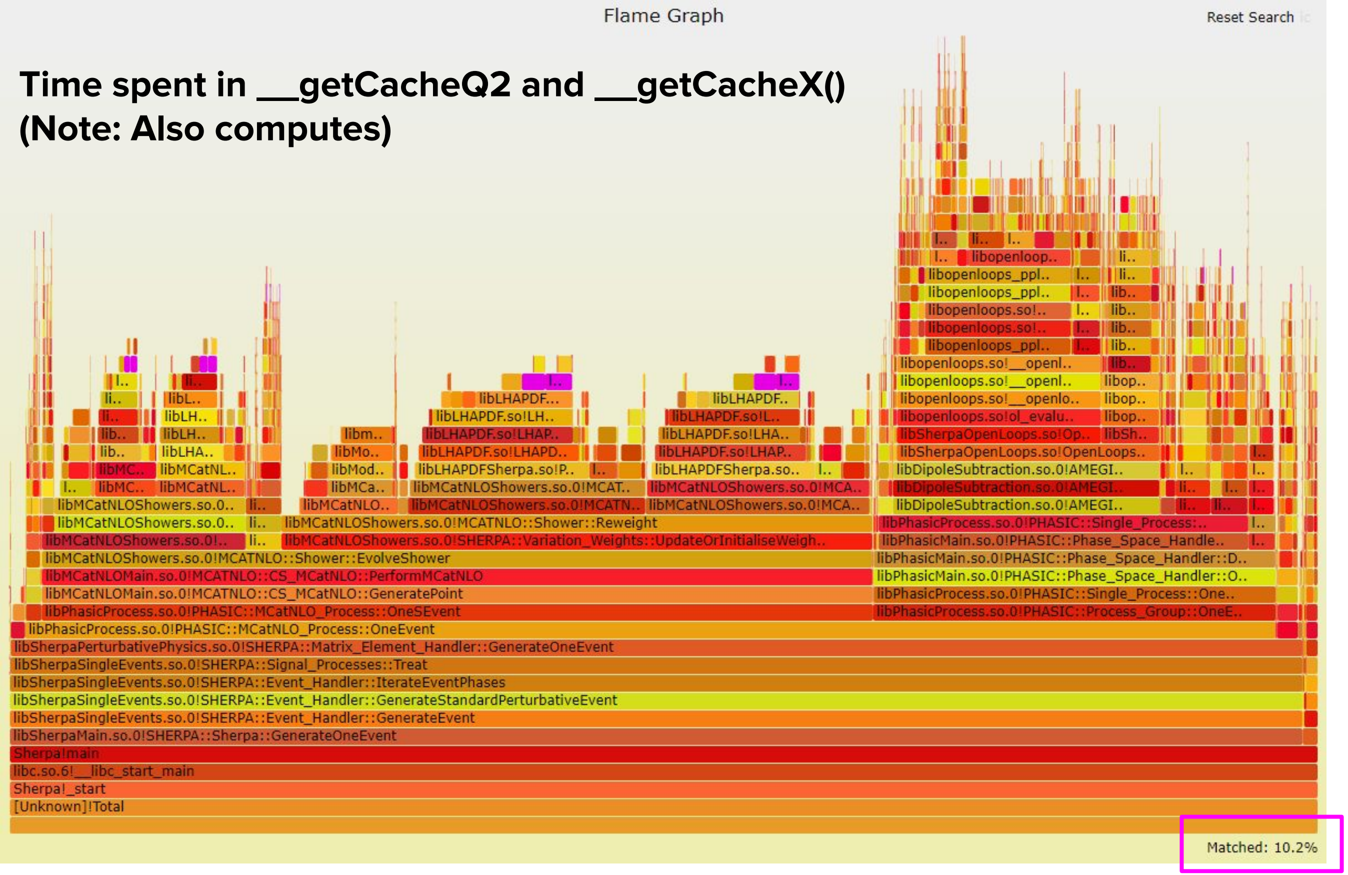
Caching in LHAPDF

Tested:
With 6.2.4beta1
With 6.3.0beta1
With 6.3.0beta3

- Investigating caching of values in LHAPDF
  - Some work carried out previously by Dima Konstantinov and Grigorii Latyshev
  - Additional work by Andy Buckley
- Iterations with implementing small thread-local caches **(current size: 4)**.
  - **Avoid re-interpolation** when the same value is requested multiple times in a single event.
- May also benefit from revisiting how Sherpa structures its LHAPFD calls.
- May also benefit from caching over different grids in LHAPDF.

Version	**% in LHAPDF**	**Total Time**
6.2.4	47.3%	19876 s
6.2.4beta1	43.9%	20235 s
6.3.0beta1	44.3%	20505 s
6.3.0beta2	43.7%	19634 s

6.3.0beta3


Flame Graph
Reset Search
libopenloop..
libopenloops_ppl..
libopenloops.so!..
libopenloops.so!__openl..
libopenloops.so!ol_evalu..
libSherpaOpenLoops.so!Op..
libSherpaOpenLoops.so!OpenLoops..
libDipoleSubtraction.so.0!AMEGI..
libLHAPDF...
libLHAPDF.so!LH..
libLHAPDF.so!LHAP..
libLHAPDF.so!LHAPD..
libLHAPDFSherpa.so!P..
libLHAPDF.so!L..
libLHAPDF.so!LHA..
libLHAPDFSherpa.so..
libMCatNLOShowers.so.0!MCAT..
libMCatNLOShowers.so.0!MCATN..
libMCatNLOShowers.so.0!MCA..
libMCatNLOShowers.so.0..
libMCatNLOShowers.so.0!..
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWeigh..
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent
libPhasicProcess.so.0!PHASIC::Single_Process:..
libPhasicMain.so.0!PHASIC::Phase_Space_Handle..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::D..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::O..
libPhasicProcess.so.0!PHASIC::Single_Process::One..
libPhasicProcess.so.0!PHASIC::Process_Group::OneE..
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::GenerateOneEvent
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPerturbativeEvent
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent
Sherpa!main
libc.so.6!__libc_start_main
Sherpa!_start
[Unknown]!Total
Matched: 10.2%

Time spent in __getCacheQ2 and __getCacheX() (Note: Also computes)

Summary

- Sherpa W+jets is a known huge CPU consumer on ATLAS
- CPU savings can be made by use of Intel’s maths library, more may be possible via vectorized maths libraries.
- Better integration with LHAPDF could yield larger saving still.
- Flamegraphs at https://cernbox.cern.ch/index.php/s/9OK2W17XELp6Gmt

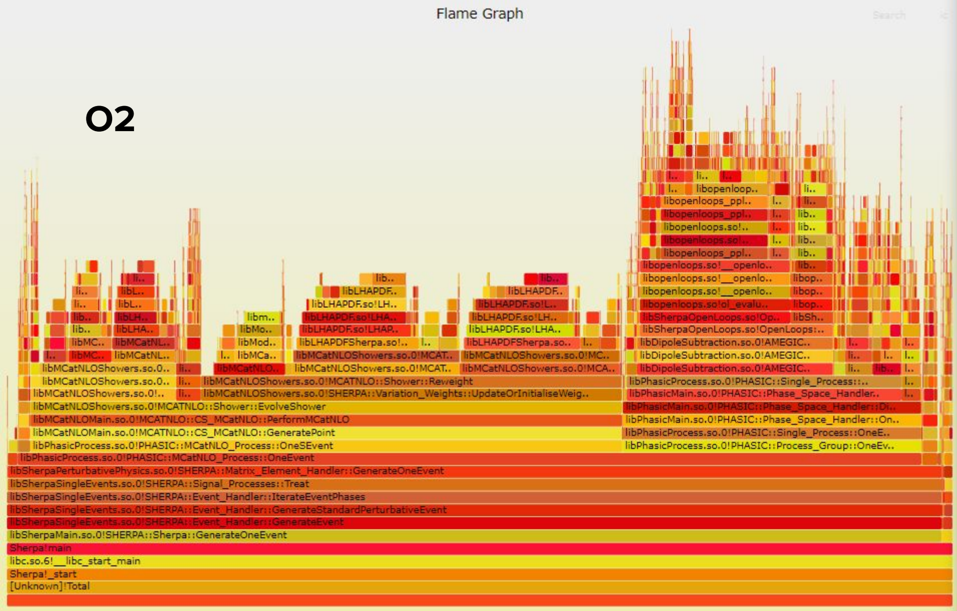
Backup

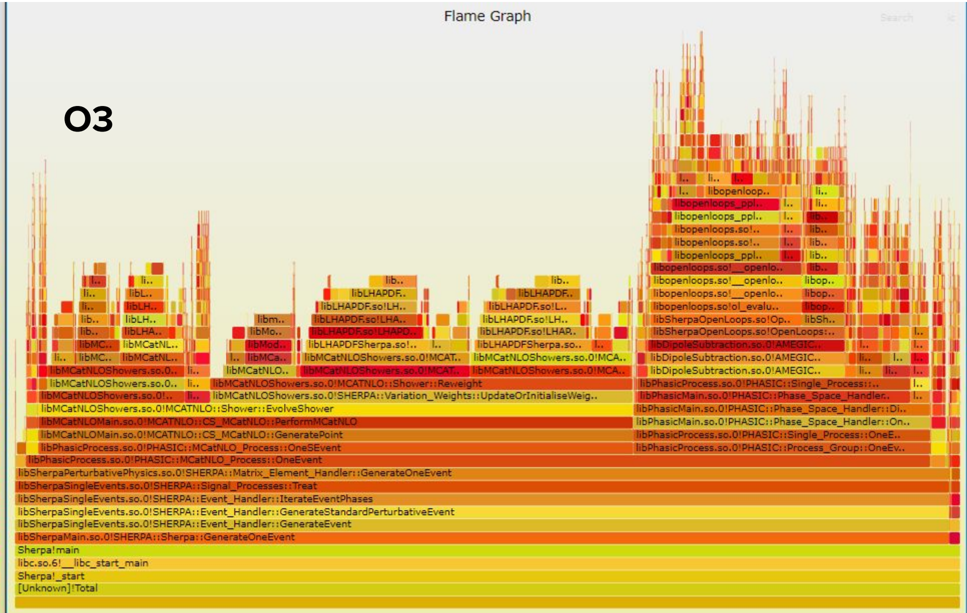
Optimisations #1: malloc

- `malloc` consumes 1.7% and `operator new()` consumes 0.9%
- TCMalloc : Thread-Caching Malloc
- *“TCMalloc is Google's customized implementation of C's malloc() and C++'s operator new used for memory allocation within our C and C++ code. TCMalloc is a fast, multi-threaded malloc implementation.”*
- Around 2.3x faster than `malloc`, used by ATLAS
- Unfortunately, TCMalloc did not play nice with VTune. Just timed with **time**
- **Sherpa + TCMalloc: 19,505 s (-2%)**

Optimisations #2: -O3

- Effects of turning on higher levels of compiler optimisation in Sherpa.
- Very little change to call-graph, and to total time.
- **Sherpa -O3: 19,506s (-2%).**





*IEEE 754 Violating

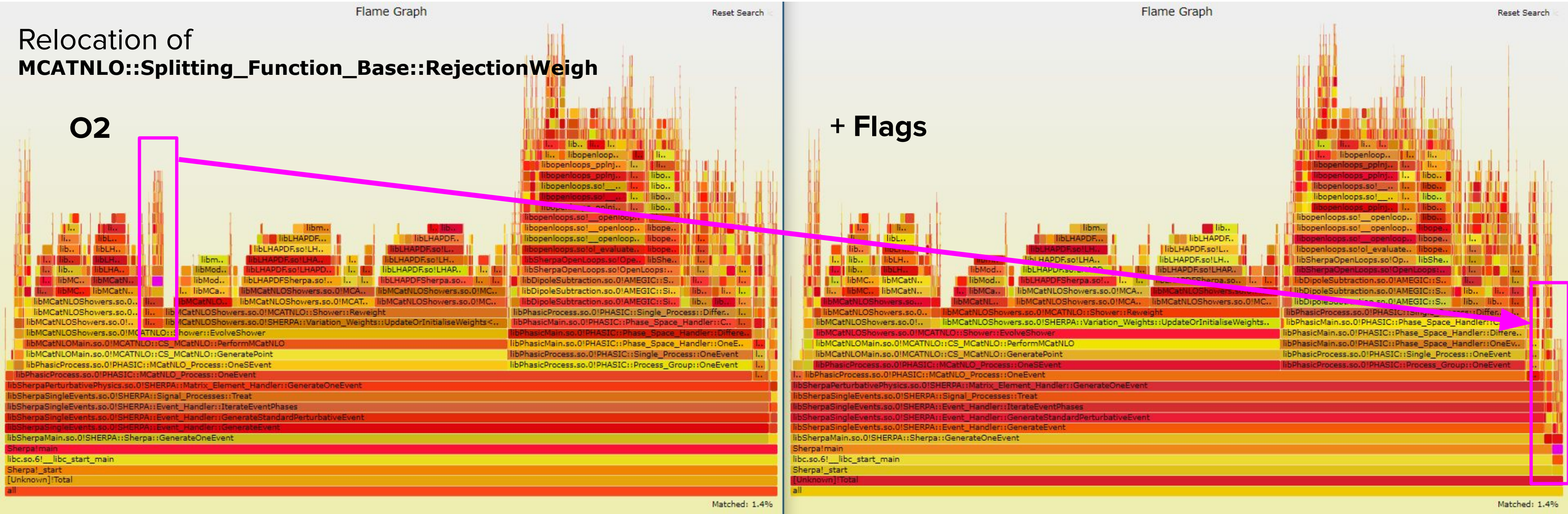
Optimisations #3: Architecture & Unsafe Maths

- **`-msse4.2`** specifies to use the SSE4.2 CPU instruction set extension.
  - Available since Nehalem (initial core i5, i7), November 2008
  - LHCb reported having fully switched over to this instruction set.
  - ATLAS has recent experience of some grid nodes and user machines *still* not supporting it.
- **`-ffast-math`** applies a bunch of "unsafe"* operations, not applied by -O.
  - **`-fno-trapping-math, -fno-signaling-nans`**: *User **cannot trap /0** or overflow.*
  - **`-funsafe-math-optimizations`**: *This mode enables optimizations that allow arbitrary reassociations and transformations with no accuracy guarantees. Due to roundoff errors the associative law of algebra do not necessary hold for floating point numbers and thus **expressions like (x + y) + z are not necessary equal to x + (y + z)***
  - **`-ffinite-math-only`**: *Assume that there will **never be NaNs or +-Infs***
  - **`-fno-errno-math`**: *Disables setting of the errno variable as required by C89/C99 on calling math library routines.*
  - **`-fno-rounding-math`**: *IEEE has four rounding modes. This flag assumes that the rounding mode is round to nearest.*
  - **`-fcx-limited-range`**: *Causes the **range reduction step to be omitted when performing complex division**. This uses a / b = ((ar*br + ai*bi)/t) + i((ai*br - ar*bi)/t) with t = br*br + bi*bi and might not work well on arbitrary ranges of the inputs.*
  - **`-fno-signed-zeros`**: ***Removes the ability to have signed 0***

Optimisations #3: Architecture & Unsafe Maths

- Again, few changes to the call graph.
- Physics output not yet checked!
- **Sherpa -msse4.2 -ffast-math: 20,839 s (+5%)**

Needs re-running, other cores were in use...



Relocation of
MCATNLO::Splitting_Function_Base::RejectionWeigh

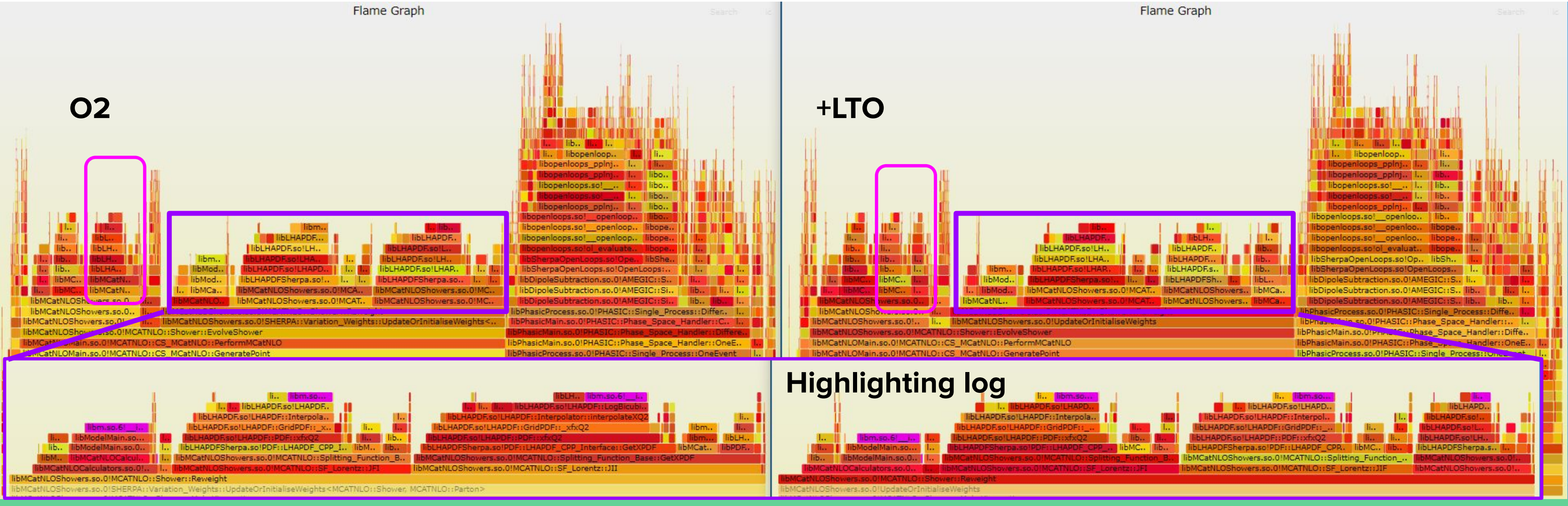
O2

+ Flags

Flame Graph
Reset Search
libopenloops.so!__openloop..
libSherpaOpenLoops.so!OpenLoops::..
libDipoleSubtraction.so.0!AMEGIC::Si..
libPhasicProcess.so.0!PHASIC::Single_Process::Differ..
libPhasicMain.so.0!PHASIC::Phase_Space_Handler::OneE..
libPhasicProcess.so.0!PHASIC::Single_Process::OneEvent
libPhasicProcess.so.0!PHASIC::Process_Group::OneEvent
libLHAPDFSherpa.so!..
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWeights<..
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::GenerateOneEvent
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPerturbativeEvent
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent
Sherpa!main
libc.so.6!__libc_start_main
Sherpa!_start
[Unknown]!Total
all
Matched: 1.4%

Optimisations #4: Link Time Optimisation

- `-lto`: *Link time optimization is implemented as a GCC front end for a bytecode representation of GIMPLE that is emitted in special sections of .o files.*
- Additional data are generated by the compiler and passed via the .o files to the linker in order to allow it to perform additional optimisaiton.
- Total time: 20,371s (+2%)



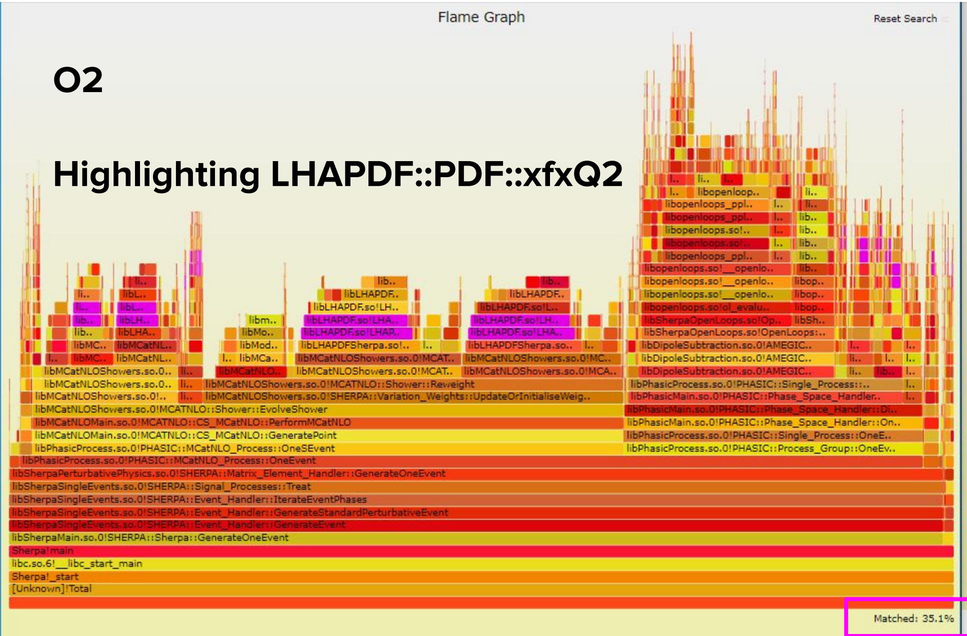
O2

+LTO

Highlighting log

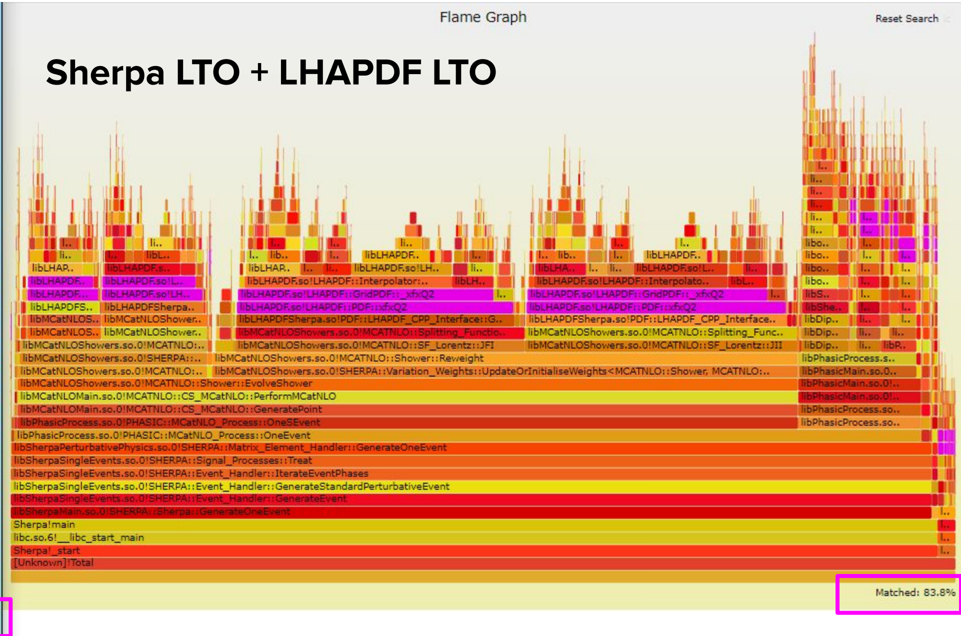
Other permutations:

- Trying to spread the flags also to LHAPDF encountered a serious regression!
  - O2: **40 s/event**
  - Sherpa O3 + LHAPDF O3 + OPENLOOPS fortran O3: **40 s/event**
  - Sherpa + TCMalloc , LHAPDF + TCMalloc: **167 s/event (!!!)**
  - Sherpa LTO + LHAPDF LTO: **161 s/event (!!!), 150 s/event (!!!)**
  - Sherpa Fast Maths flags + LHAPDF Fast Maths flags: **152 s/event (!!!)**



O2

Highlighting LHAPDF::PDF::xfxQ2



Sherpa LTO + LHAPDF LTO

Other permutations:

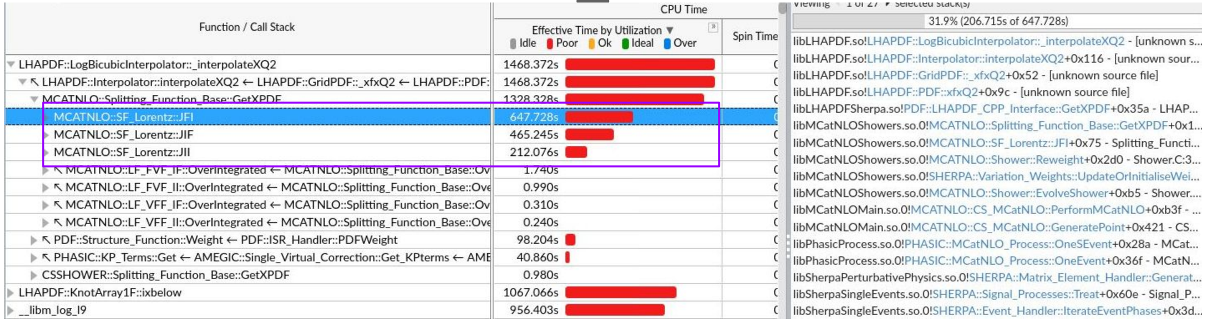
- Trying a fully static build of Sherpa.
  - Tried to link Sherpa against minimal set of dependencies.
  - Build / combine static `.a` files for all required libraries.
  - Link them all together statically
- Managed to make a giant binary.
- Couldn’t get it to work… segfaults…

Intel

- Proprietary compiler, but licencing may be available through CERN
- **Note**: ATLAS preload the intel maths libraries
- Using `icc 16.0.3 20160415` licenced by Warwick
- Total time: **18,025s**
  - **10% faster than GCC**

CPU #1: **LHAPDF::LogBicubicInterpolator::_interpolateXQ2**

- Predominantly split over **`SF_Lorentz:JFI, JIF, JII`**



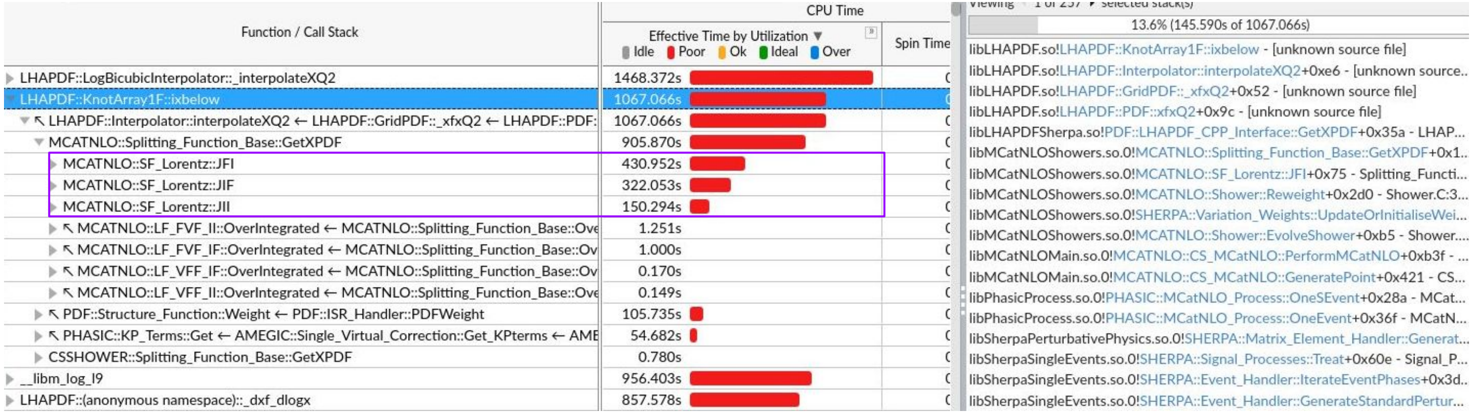
Function / Call Stack	CPU Time Effective Time by Utilization ▼ ▮ Idle ▮ Poor ▮ Ok ▮ Ideal ▮ Over	Spin Time
▼ LHAPDF::LogBicubicInterpolator::_interpolateXQ2	1468.372s	
▼ ↖ LHAPDF::Interpolator::interpolateXQ2 ← LHAPDF::GridPDF::_xfxQ2 ← LHAPDF::PDF:	1468.372s	
▼ MCATNLO::Splitting_Function_Base::GetXPDF	1328.328s	
MCATNLO::SF_Lorentz::JFI	647.728s	
MCATNLO::SF_Lorentz::JIF	465.245s	
MCATNLO::SF_Lorentz::JII	212.076s	
▶ ↖ MCATNLO::LF_FVF_IF::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ov	1.740s	
▶ ↖ MCATNLO::LF_FVF_II::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ove	0.990s	
▶ ↖ MCATNLO::LF_VFF_IF::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ov	0.310s	
▶ ↖ MCATNLO::LF_VFF_II::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ove	0.240s	
▶ ↖ PDF::Structure_Function::Weight ← PDF::ISR_Handler::PDFWeight	98.204s	
▶ ↖ PHASIC::KP_Terms::Get ← AMEGIC::Single_Virtual_Correction::Get_KPterms ← AME	40.860s	
▶ CSSHOWER::Splitting_Function_Base::GetXPDF	0.980s	
▶ LHAPDF::KnotArray1F::ixbelow	1067.066s	
▶ __libm_log_l9	956.403s	

Viewing ◂ 1 of 27 ▸ selected stack(s)

31.9% (206.715s of 647.728s)

libLHAPDF.so!LHAPDF::LogBicubicInterpolator::_interpolateXQ2 - [unknown s...
libLHAPDF.so!LHAPDF::Interpolator::interpolateXQ2+0x116 - [unknown sour...
libLHAPDF.so!LHAPDF::GridPDF::_xfxQ2+0x52 - [unknown source file]
libLHAPDF.so!LHAPDF::PDF::xfxQ2+0x9c - [unknown source file]
libLHAPDFSherpa.so!PDF::LHAPDF_CPP_Interface::GetXPDF+0x35a - LHAP...
libMCatNLOShowers.so.0!MCATNLO::Splitting_Function_Base::GetXPDF+0x1...
libMCatNLOShowers.so.0!MCATNLO::SF_Lorentz::JFI+0x75 - Splitting_Functi...
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight+0x2d0 - Shower.C:3...
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWei...
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower+0xb5 - Shower....
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO+0xb3f - ...
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint+0x421 - CS...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent+0x28a - MCat...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0x36f - MCatN...
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::Generat...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x60e - Signal_P...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x3d...

CPU #2: **LHAPDF::KnotArray1F::ixbelow**



Function / Call Stack	CPU Time Effective Time by Utilization ▼ ▮ Idle ▮ Poor ▮ Ok ▮ Ideal ▮ Over	Spin Time
▶ LHAPDF::LogBicubicInterpolator::_interpolateXQ2	1468.372s	
▼ LHAPDF::KnotArray1F::ixbelow	1067.066s	
▼ ↖ LHAPDF::Interpolator::interpolateXQ2 ← LHAPDF::GridPDF::_xfxQ2 ← LHAPDF::PDF:	1067.066s	
▼ MCATNLO::Splitting_Function_Base::GetXPDF	905.870s	
▶ MCATNLO::SF_Lorentz::JFI	430.952s	
▶ MCATNLO::SF_Lorentz::JIF	322.053s	
▶ MCATNLO::SF_Lorentz::JII	150.294s	
▶ ↖ MCATNLO::LF_FVF_II::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ove	1.251s	
▶ ↖ MCATNLO::LF_FVF_IF::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ov	1.000s	
▶ ↖ MCATNLO::LF_VFF_IF::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ov	0.170s	
▶ ↖ MCATNLO::LF_VFF_II::OverIntegrated ← MCATNLO::Splitting_Function_Base::Ove	0.149s	
▶ ↖ PDF::Structure_Function::Weight ← PDF::ISR_Handler::PDFWeight	105.735s	
▶ ↖ PHASIC::KP_Terms::Get ← AMEGIC::Single_Virtual_Correction::Get_KPterms ← AME	54.682s	
▶ CSSHOWER::Splitting_Function_Base::GetXPDF	0.780s	
▶ __libm_log_l9	956.403s	
▶ LHAPDF::(anonymous namespace)::_dxf_dlogx	857.578s	

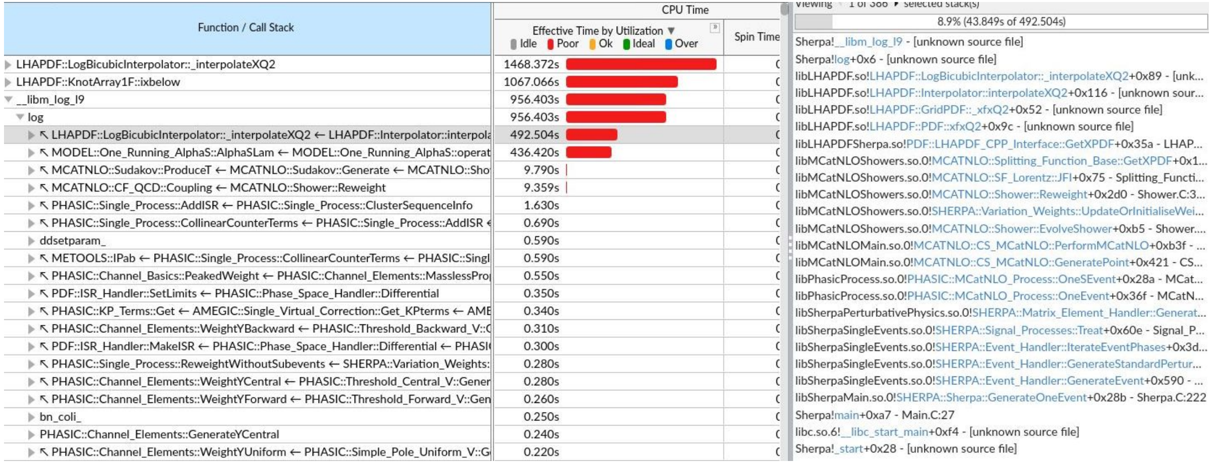
Viewing ◂ 1 of 257 ▸ selected stack(s)

13.6% (145.590s of 1067.066s)

libLHAPDF.so!LHAPDF::KnotArray1F::ixbelow - [unknown source file]
libLHAPDF.so!LHAPDF::Interpolator::interpolateXQ2+0xe6 - [unknown source..
libLHAPDF.so!LHAPDF::GridPDF::_xfxQ2+0x52 - [unknown source file]
libLHAPDF.so!LHAPDF::PDF::xfxQ2+0x9c - [unknown source file]
libLHAPDFSherpa.so!PDF::LHAPDF_CPP_Interface::GetXPDF+0x35a - LHAP...
libMCatNLOShowers.so.0!MCATNLO::Splitting_Function_Base::GetXPDF+0x1..
libMCatNLOShowers.so.0!MCATNLO::SF_Lorentz::JFI+0x75 - Splitting_Functi...
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight+0x2d0 - Shower.C:3...
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWei...
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower+0xb5 - Shower....
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO+0xb3f - ...
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint+0x421 - CS...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent+0x28a - MCat...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0x36f - MCatN...
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::Generat...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x60e - Signal_P...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x3d..
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPertur...

CPU #3: __libm_log_l9

- Log takes the #3 slot, calls from
  - LHAPDF::Interpolator::interpolateXQ2
  - MODEL::One_Running_AlphaS::operator()



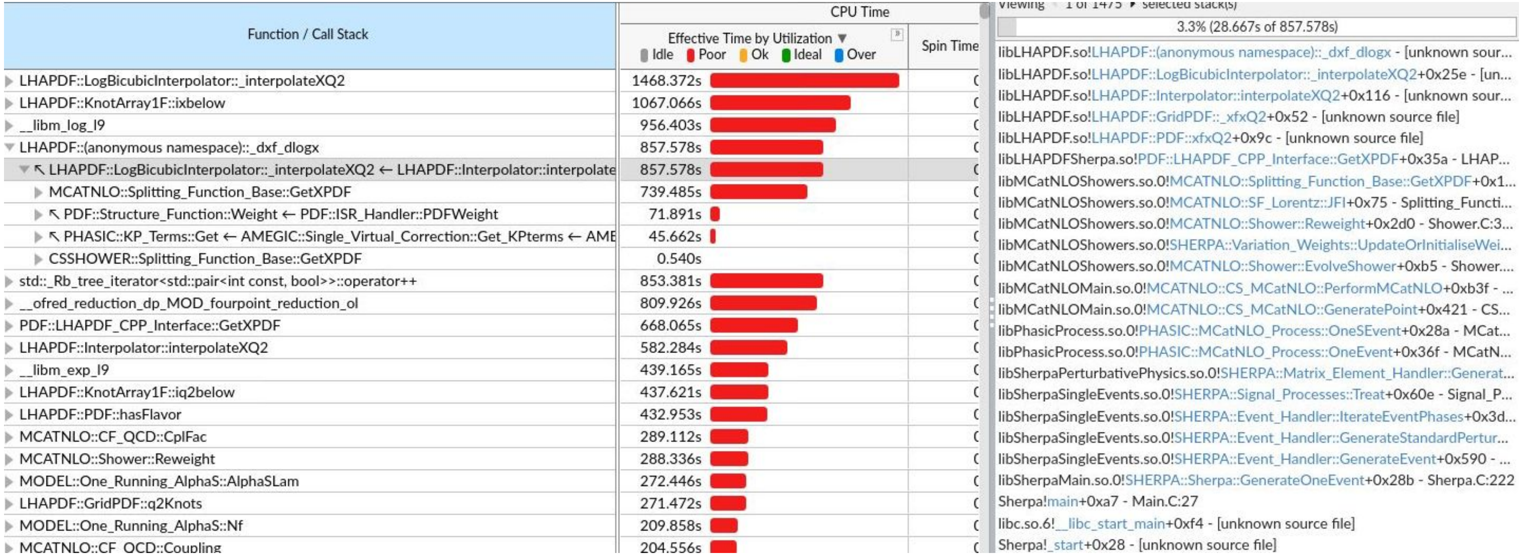
	CPU Time	
Function / Call Stack	Effective Time by Utilization ▼ ● Idle ● Poor ● Ok ● Ideal ● Over	Spin Time
▶ LHAPDF::LogBicubicInterpolator::_interpolateXQ2	1468.372s	0
▶ LHAPDF::KnotArray1F::ixbelow	1067.066s	0
▼ __libm_log_l9	956.403s	0
▼ log	956.403s	0
▶ ↖ LHAPDF::LogBicubicInterpolator::_interpolateXQ2 ← LHAPDF::Interpolator::interpola	492.504s	0
▶ ↖ MODEL::One_Running_AlphaS::AlphaSLam ← MODEL::One_Running_AlphaS::operat	436.420s	0
▶ ↖ MCATNLO::Sudakov::ProduceT ← MCATNLO::Sudakov::Generate ← MCATNLO::Sho	9.790s	0
▶ ↖ MCATNLO::CF_QCD::Coupling ← MCATNLO::Shower::Reweight	9.359s	0
▶ ↖ PHASIC::Single_Process::AddISR ← PHASIC::Single_Process::ClusterSequenceInfo	1.630s	0
▶ ↖ PHASIC::Single_Process::CollinearCounterTerms ← PHASIC::Single_Process::AddISR ←	0.690s	0
▶ ddsetparam_	0.590s	0
▶ ↖ METOOLS::IPab ← PHASIC::Single_Process::CollinearCounterTerms ← PHASIC::Singl	0.590s	0
▶ ↖ PHASIC::Channel_Basics::PeakedWeight ← PHASIC::Channel_Elements::MasslessPro	0.550s	0
▶ ↖ PDF::ISR_Handler::SetLimits ← PHASIC::Phase_Space_Handler::Differential	0.350s	0
▶ ↖ PHASIC::KP_Terms::Get ← AMEGIC::Single_Virtual_Correction::Get_KPterms ← AME	0.340s	0
▶ ↖ PHASIC::Channel_Elements::WeightYBackward ← PHASIC::Threshold_Backward_V::G	0.310s	0
▶ ↖ PDF::ISR_Handler::MakeISR ← PHASIC::Phase_Space_Handler::Differential ← PHASIC	0.300s	0
▶ ↖ PHASIC::Single_Process::ReweightWithoutSubevents ← SHERPA::Variation_Weights:	0.280s	0
▶ ↖ PHASIC::Channel_Elements::WeightYCentral ← PHASIC::Threshold_Central_V::Gener	0.280s	0
▶ ↖ PHASIC::Channel_Elements::WeightYForward ← PHASIC::Threshold_Forward_V::Gen	0.260s	0
▶ bn_coli_	0.250s	0
▶ PHASIC::Channel_Elements::GenerateYCentral	0.240s	0
▶ ↖ PHASIC::Channel_Elements::WeightYUniform ← PHASIC::Simple_Pole_Uniform_V::G	0.220s	0

Viewing ◀ 1 of 386 ▶ selected stack(s)

8.9% (43.849s of 492.504s)

```
Sherpa!__libm_log_l9 - [unknown source file]
Sherpa!log+0x6 - [unknown source file]
libLHAPDF.so!LHAPDF::LogBicubicInterpolator::_interpolateXQ2+0x89 - [unk...
libLHAPDF.so!LHAPDF::Interpolator::interpolateXQ2+0x116 - [unknown sour...
libLHAPDF.so!LHAPDF::GridPDF::_xfxQ2+0x52 - [unknown source file]
libLHAPDF.so!LHAPDF::PDF::xfxQ2+0x9c - [unknown source file]
libLHAPDFSherpa.so!PDF::LHAPDF_CPP_Interface::GetXPDF+0x35a - LHAP...
libMCatNLOShowers.so.0!MCATNLO::Splitting_Function_Base::GetXPDF+0x1...
libMCatNLOShowers.so.0!MCATNLO::SF_Lorentz::JFI+0x75 - Splitting_Functi...
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight+0x2d0 - Shower.C:3...
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWei...
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower+0xb5 - Shower....
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO+0xb3f - ...
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint+0x421 - CS...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent+0x28a - MCat...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0x36f - MCatN...
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::Generat...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x60e - Signal_P...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x3d...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPertur...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent+0x590 - ...
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent+0x28b - Sherpa.C:222
Sherpa!main+0xa7 - Main.C:27
libc.so.6!__libc_start_main+0xf4 - [unknown source file]
Sherpa!_start+0x28 - [unknown source file]
```

CPU #4: _dxf_dlogx



Function / Call Stack	CPU Time Effective Time by Utilization ▼ ▮ Idle ▮ Poor ▮ Ok ▮ Ideal ▮ Over	Spin Time
▶ LHAPDF::LogBicubicInterpolator::_interpolateXQ2	1468.372s	
▶ LHAPDF::KnotArray1F::ixbelow	1067.066s	
▶ __libm_log_l9	956.403s	
▼ LHAPDF::(anonymous namespace)::_dxf_dlogx	857.578s	
▼ ↖ LHAPDF::LogBicubicInterpolator::_interpolateXQ2 ← LHAPDF::Interpolator::interpolate	857.578s	
▶ MCATNLO::Splitting_Function_Base::GetXPDF	739.485s	
▶ ↖ PDF::Structure_Function::Weight ← PDF::ISR_Handler::PDFWeight	71.891s	
▶ ↖ PHASIC::KP_Terms::Get ← AMEGIC::Single_Virtual_Correction::Get_KPterms ← AME	45.662s	
▶ CSSHOWER::Splitting_Function_Base::GetXPDF	0.540s	
▶ std::_Rb_tree_iterator<std::pair<int const, bool>>::operator++	853.381s	
▶ __ofred_reduction_dp_MOD_fourpoint_reduction_ol	809.926s	
▶ PDF::LHAPDF_CPP_Interface::GetXPDF	668.065s	
▶ LHAPDF::Interpolator::interpolateXQ2	582.284s	
▶ __libm_exp_l9	439.165s	
▶ LHAPDF::KnotArray1F::iq2below	437.621s	
▶ LHAPDF::PDF::hasFlavor	432.953s	
▶ MCATNLO::CF_QCD::CplFac	289.112s	
▶ MCATNLO::Shower::Reweight	288.336s	
▶ MODEL::One_Running_AlphaS::AlphaSLam	272.446s	
▶ LHAPDF::GridPDF::q2Knots	271.472s	
▶ MODEL::One_Running_AlphaS::Nf	209.858s	
▶ MCATNLO::CF_QCD::Coupling	204.556s	

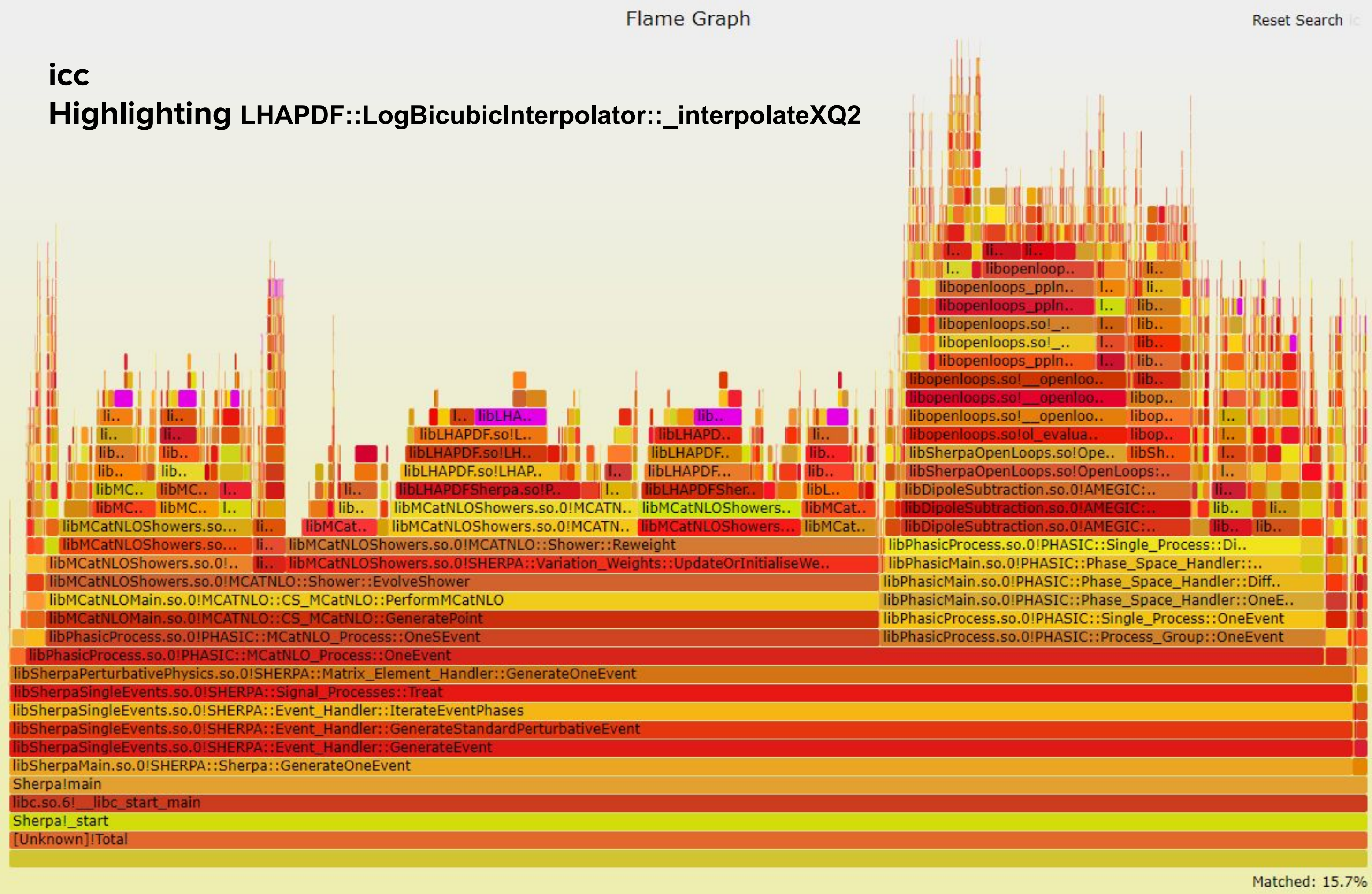
Viewing ◂ 1 of 1475 ▸ selected stack(s)

3.3% (28.667s of 857.578s)

```
libLHAPDF.so!LHAPDF::(anonymous namespace)::_dxf_dlogx - [unknown sour...
libLHAPDF.so!LHAPDF::LogBicubicInterpolator::_interpolateXQ2+0x25e - [un...
libLHAPDF.so!LHAPDF::Interpolator::interpolateXQ2+0x116 - [unknown sour...
libLHAPDF.so!LHAPDF::GridPDF::_xfxQ2+0x52 - [unknown source file]
libLHAPDF.so!LHAPDF::PDF::xfxQ2+0x9c - [unknown source file]
libLHAPDFSherpa.so!PDF::LHAPDF_CPP_Interface::GetXPDF+0x35a - LHAP...
libMCatNLOShowers.so.0!MCATNLO::Splitting_Function_Base::GetXPDF+0x1...
libMCatNLOShowers.so.0!MCATNLO::SF_Lorentz::JFI+0x75 - Splitting_Functi...
libMCatNLOShowers.so.0!MCATNLO::Shower::Reweight+0x2d0 - Shower.C:3...
libMCatNLOShowers.so.0!SHERPA::Variation_Weights::UpdateOrInitialiseWei...
libMCatNLOShowers.so.0!MCATNLO::Shower::EvolveShower+0xb5 - Shower....
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::PerformMCatNLO+0xb3f - ...
libMCatNLOMain.so.0!MCATNLO::CS_MCatNLO::GeneratePoint+0x421 - CS...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneSEvent+0x28a - MCat...
libPhasicProcess.so.0!PHASIC::MCatNLO_Process::OneEvent+0x36f - MCatN...
libSherpaPerturbativePhysics.so.0!SHERPA::Matrix_Element_Handler::Generat...
libSherpaSingleEvents.so.0!SHERPA::Signal_Processes::Treat+0x60e - Signal_P...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::IterateEventPhases+0x3d...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateStandardPertur...
libSherpaSingleEvents.so.0!SHERPA::Event_Handler::GenerateEvent+0x590 - ...
libSherpaMain.so.0!SHERPA::Sherpa::GenerateOneEvent+0x28b - Sherpa.C:222
Sherpa!main+0xa7 - Main.C:27
libc.so.6!__libc_start_main+0xf4 - [unknown source file]
Sherpa!_start+0x28 - [unknown source file]
```

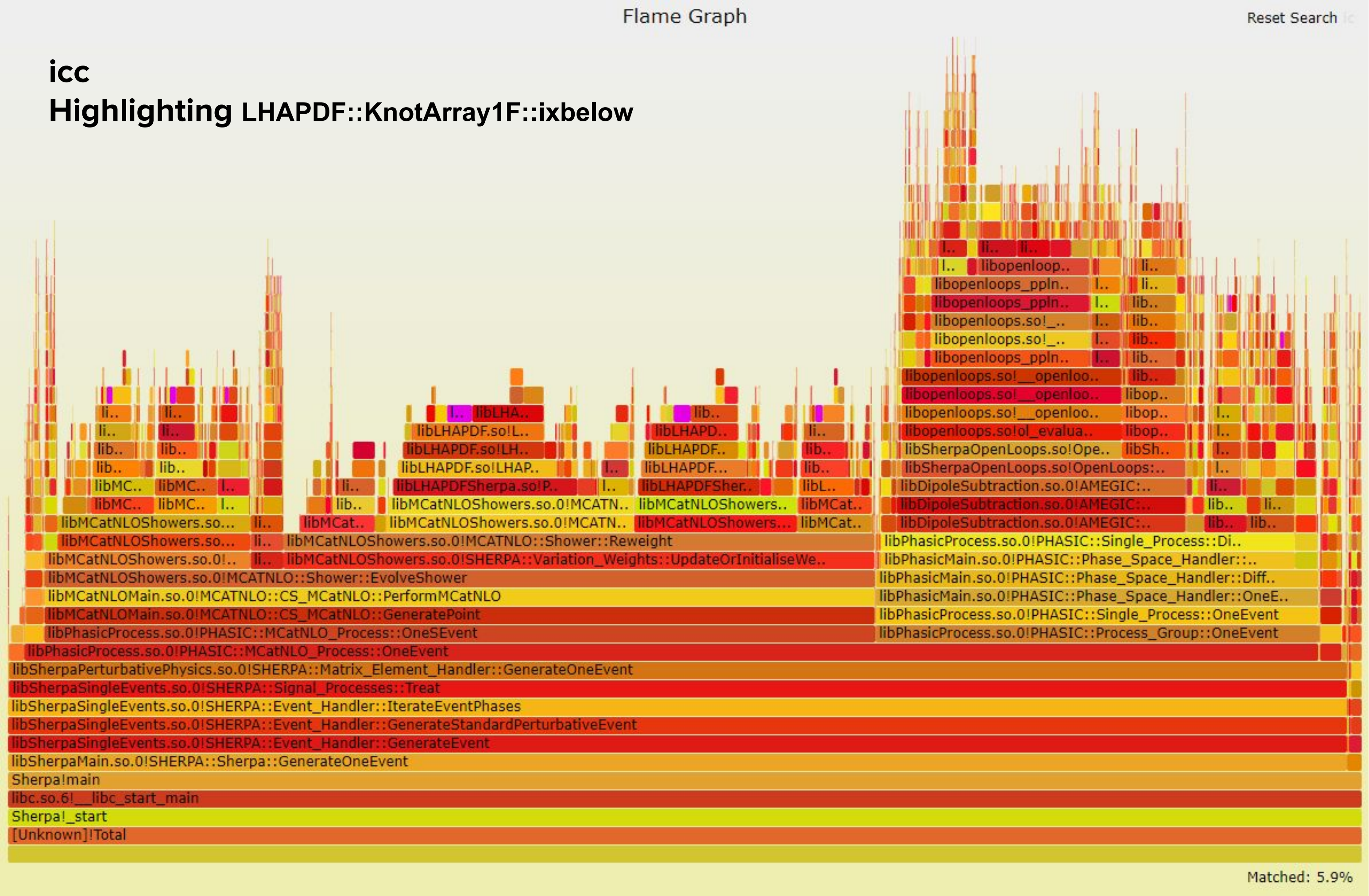
icc

Highlighting LHAPDF::LogBicubicInterpolator::_interpolateXQ2



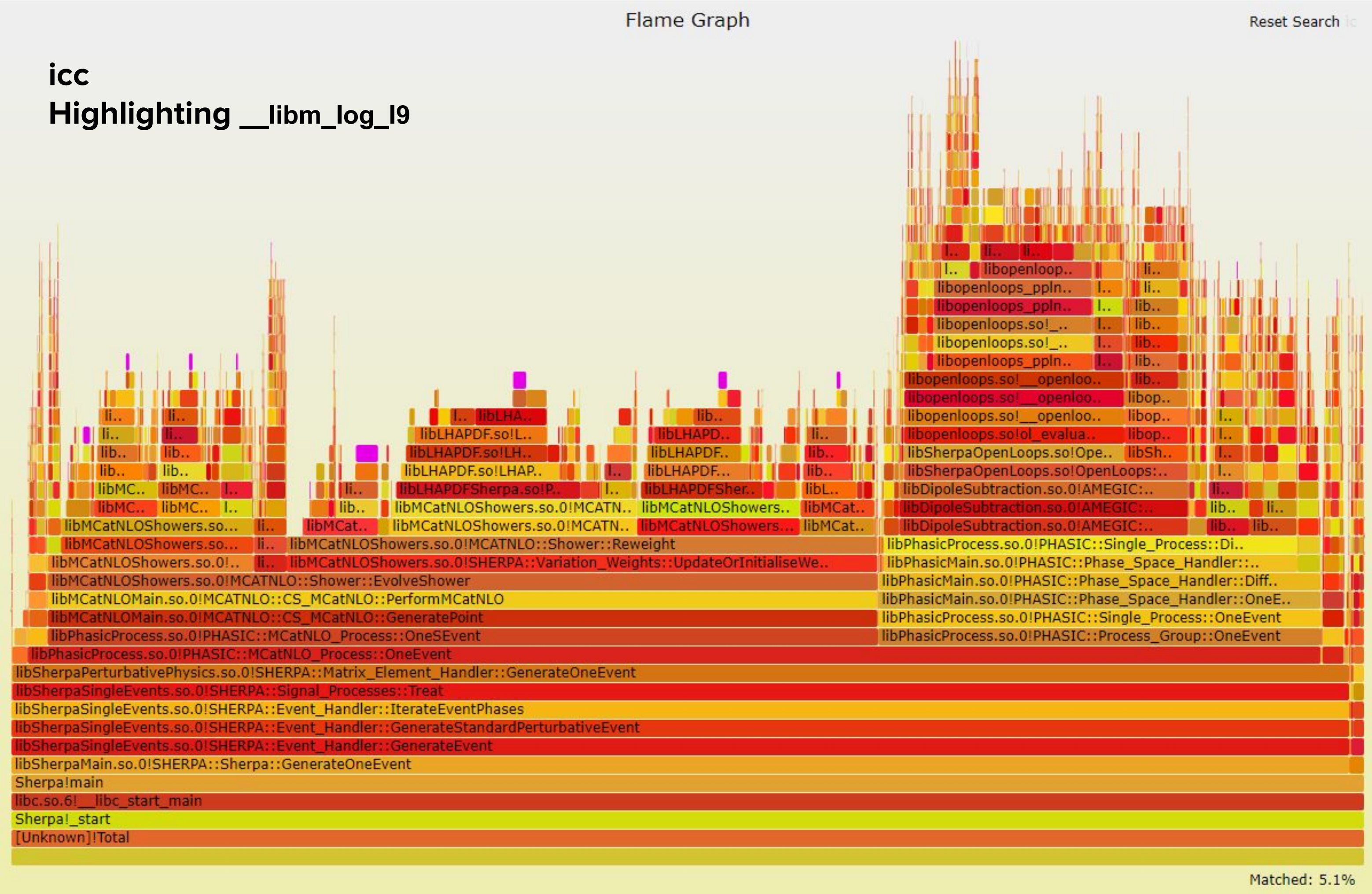
icc

Highlighting LHAPDF::KnotArray1F::ixbelow



icc

Highlighting __libm_log_l9



Intel optmisations

- Intel have their own suite of optimisation flags
- Took a little effort to find a combination which would not cause compile errors in either LHAPDF or Sherpa
  - Sherpa: **`-xSSE4.2 -O3 -no-prec-div -fp-model fast=2`**
  - LHAPDF: **`-xSSE4.2 -O3`**
- Not currently using link time optimisation (**`-flto`**), issues...
- Total **18,598 s**
  - **6% faster than GCC**