Intel® VTune™ Amplifier XE Generics

Rev.: 22/09/2015

Agenda

Introduction to Intel® VTune™ Amplifier XE profiler

High-level Features

Types of Analysis

Hotspot analysis

- Basic Hotspots
- Advanced Hotspots

Concurrency Analysis

Locks and Waits Analysis

User and Synchronization API, Frame/Task Analysis

Command Line Interface, Installation, Remote Collection

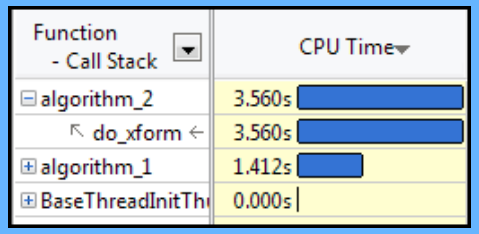
Conclusion

Intel® VTune™ Amplifier XE

Performance Profiler

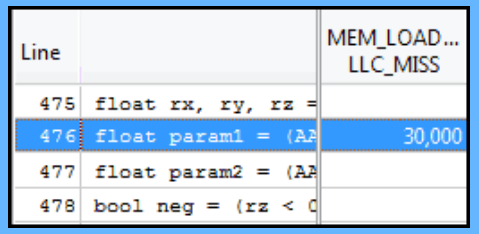
Where is my application…

Spending Time?



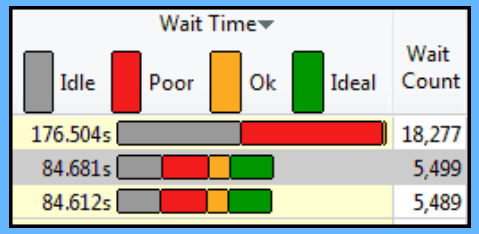
- Focus tuning on functions taking time
- See call stacks
- See time on source

Wasting Time?



- See cache misses on your source
- See functions sorted by # of cache misses

Waiting Too Long?



- See locks by wait time
- Red/Green for CPU utilization during wait

- Windows & Linux
- Low overhead
- No special recompiles

Advanced Profiling For Scalable Multicore Performance

Intel® VTune™ Amplifier XE

Tune Applications for Scalable Multicore Performance

Fast, Accurate Performance Profiles

- Hotspot (Statistical call tree)
- Call counts (Statistical)
- Hardware-Event Sampling

Thread Profiling

- Visualize thread interactions on timeline
- Balance workloads

Easy set-up

- Pre-defined performance profiles
- Use a normal production build

Find Answers Fast

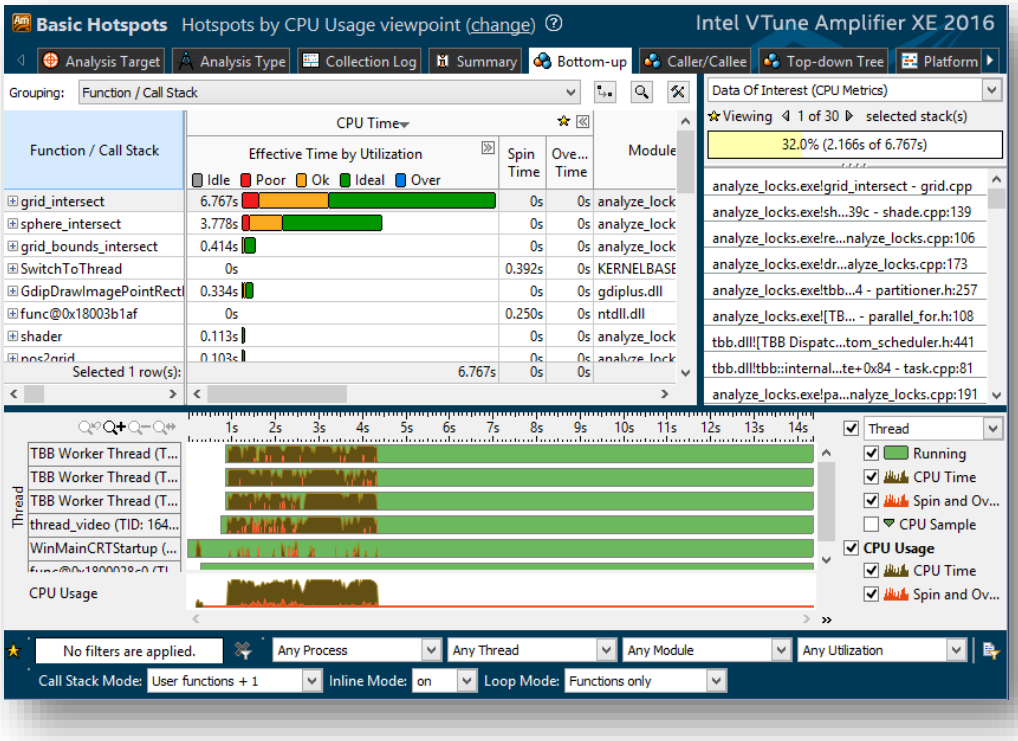
- Filter extraneous data
- View results on the source / assembly

Compatible

- Microsoft, GCC, Intel compilers
- C/C++, Fortran, Assembly, .NET, Java
- Latest Intel® processors and compatible processors[1]

Windows or Linux

- Visual Studio Integration (Windows)
- Standalone user i/f and command line
- 32 and 64-bit



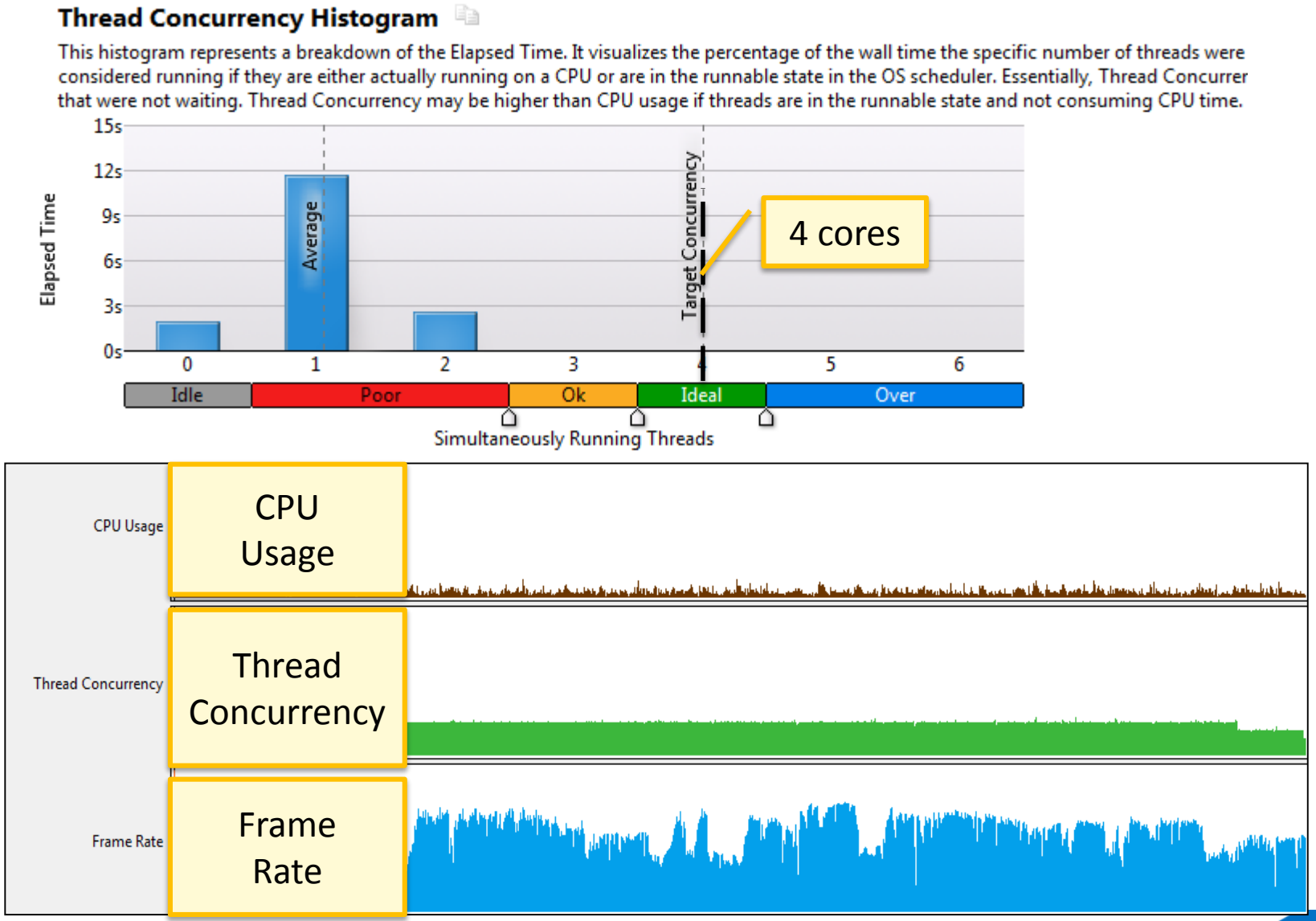
[1] IA32 and Intel® 64 architectures.
Many features work with compatible processors.
Event based sampling requires a genuine Intel® Processor.

A set of instruments to identify performance problems

Quick Overview

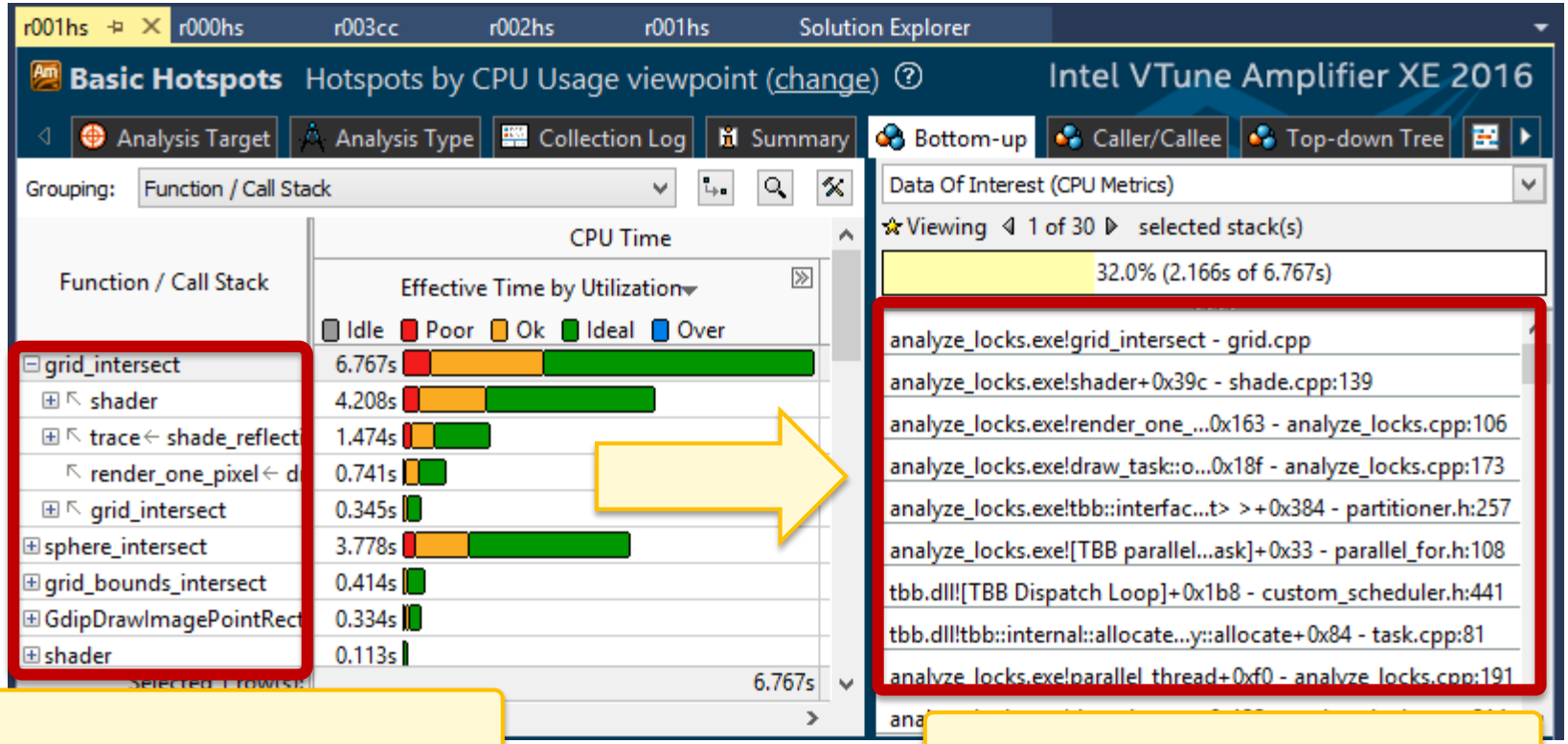
Intel® VTune™ Amplifier XE

Get a quick snapshot



Intel® VTune™ Amplifier XE

Identify hotspots



Hottest Functions

Hottest Call Stack

Quickly identify what is important

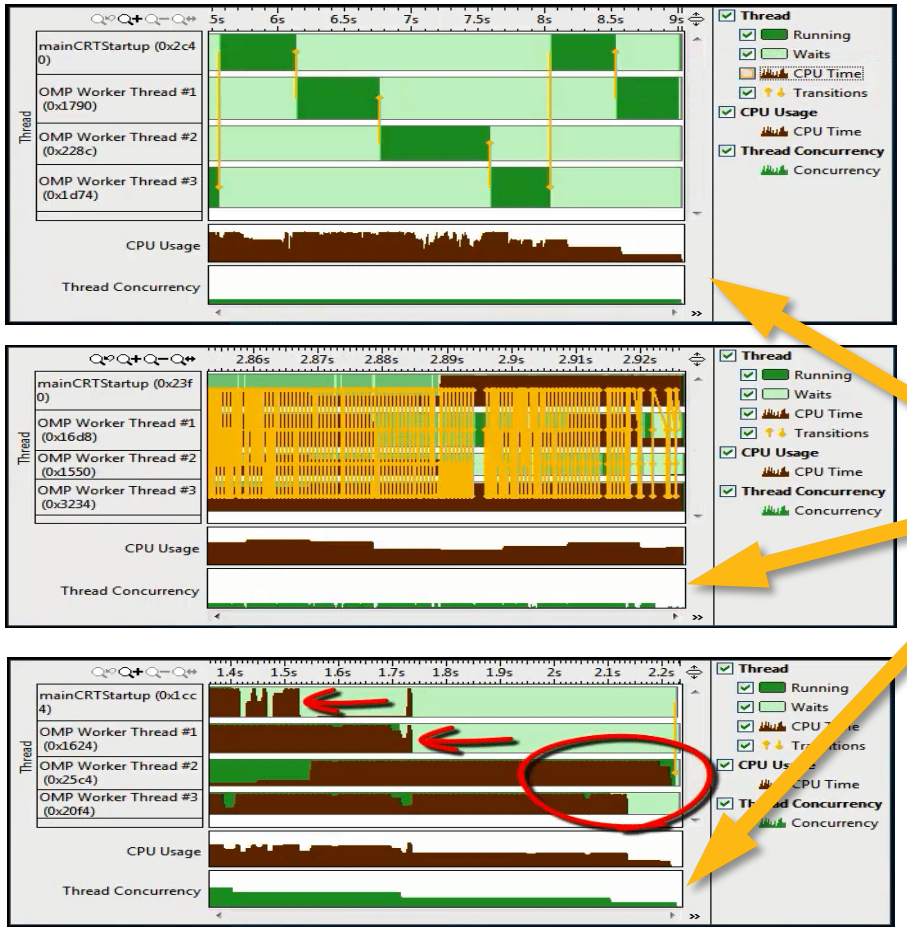
Intel® VTune™ Amplifier XE

Look for Common Patterns

Coarse Grain Locks

High Lock Contention

Load Imbalance



Low Concurrency

Intel® VTune™ Amplifier XE

Find Answers Fast

Adjust Data Grouping

- Function - Call Stack
- Module - Function - Call Stack
- Source File - Function - Call Stack
- Thread - Function - Call Stack

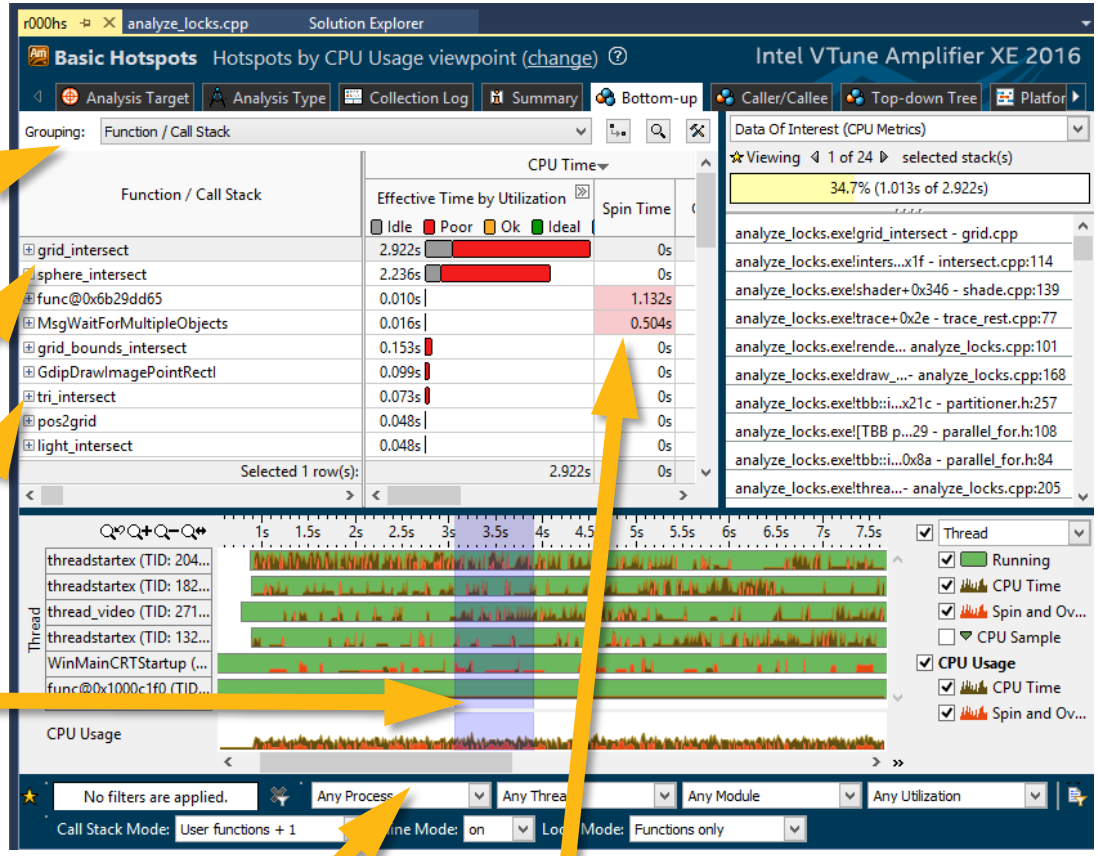
... (Partial list shown)

Double Click Function to View Source

Click [+] for Call Stack

Filter by Timeline Selection (or by Grid Selection)

- Zoom In And Filter On Selection
- Filter In by Selection
- Remove All Filters

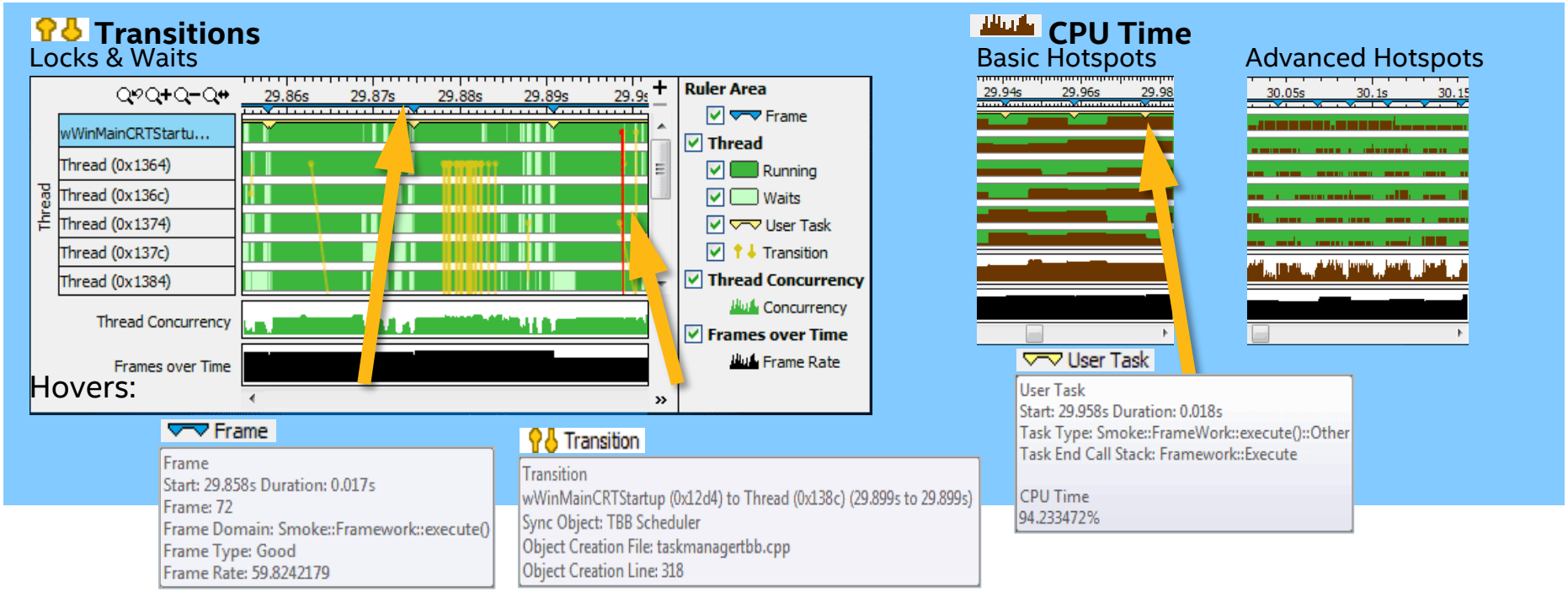


Filter by Process & Other Controls

Tuning Opportunities Shown in Pink. Hover for Tips

Intel® VTune™ Amplifier XE

Timeline Visualizes Thread Behavior



Optional: Use API to mark frames and user tasks

Optional: Add a mark during collection

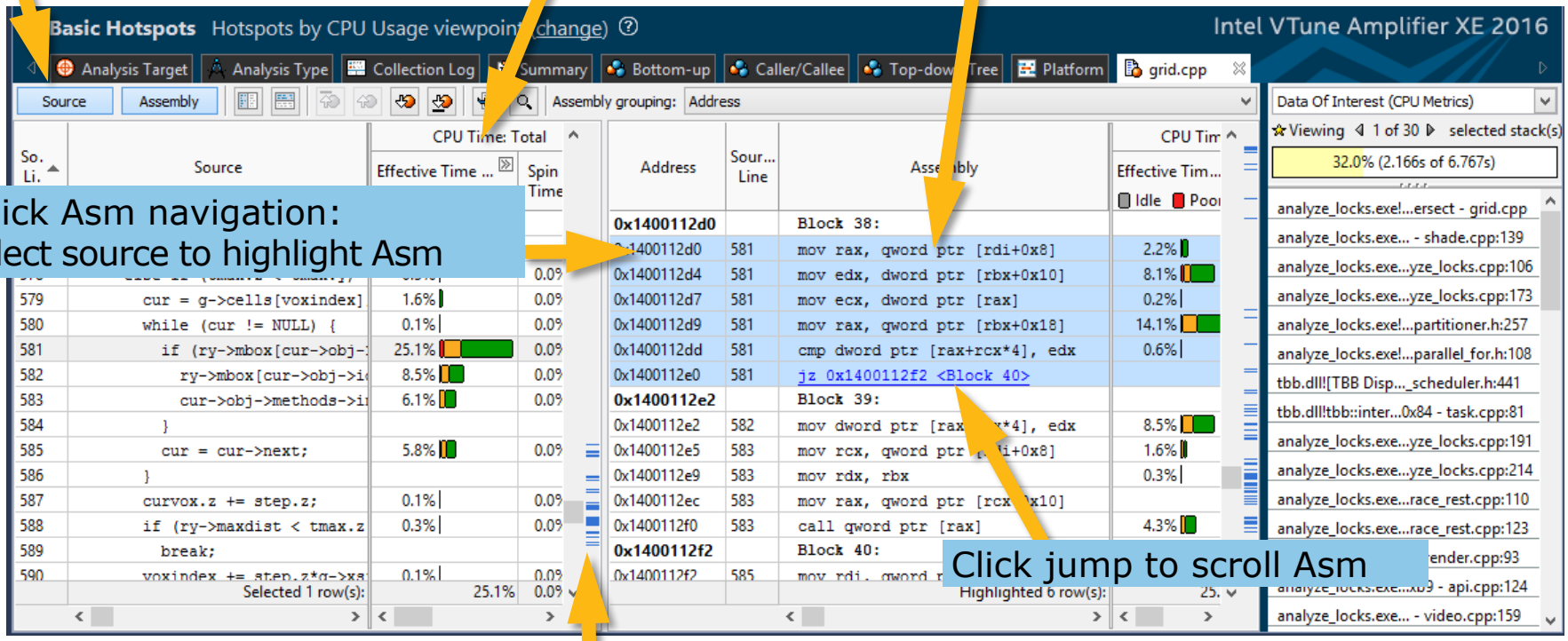
Intel® VTune™ Amplifier XE

See Profile Data On Source / Asm

View Source / Asm or both

CPU Time

Right click for instruction reference manual



Quick Asm navigation:
Select source to highlight Asm

Click jump to scroll Asm

Quickly scroll to hot spots. Scroll Bar "Heat Map" is an overview of hot spots

High-level Features

Intel® VTune™ Amplifier XE

Feature Highlights

Basic Hot Spot Analysis (Statistical Call Graph)

- Locates the time consuming regions of your application
- Provides associated call-stacks that let you know how you got to these time consuming regions
- Call-tree built using these call stacks

Advanced Hotspot and architecture analysis

- Based on Hardware Event-based Sampling (EBS)
- Pre-defined tuning experiments

Thread Profiling

- Visualize thread activity and lock transitions in the timeline
- Provides lock profiling capability
- Shows CPU/Core utilization and concurrency information

GPU Compute Performance Analysis

- Collect GPU data for tuning OpenCL applications. Correlate GPU and CPU activities

Intel® VTune™ Amplifier XE

Feature Highlights

Attach to running processes

- Hotspot and Concurrency analysis modes can attach to running processes

System wide data collection

- EBS modes allows system wide data collection and the tool provides the ability to filter this data

GUI

- Standalone GUI available on Windows* and Linux
- Microsoft* Visual Studio integration

Command Line

- Comprehensive support for regression analysis and remote collection

Platform & application support

- Windows* and Linux (Android, Tizen, Yocto – in the ISS)
- Microsoft* .NET/C# applications
- Java* and mixed applications
- Fortran applications

Intel® VTune™ Amplifier XE

Feature Highlights

Event multiplexing

- Gather more information with each profiling run

Timeline correlation of thread and event data

- Populates thread active time with event data collected for that thread
- Ability to filter regions on the timeline

Advanced Source / Assembler View

- See event data graphed on the source / assembler
- View and analyze assembly as basic blocks
- Review the quality of vectorization in the assembly code display of your hot spot

Provides pre-defined tuning experiments

- Predefined profiles for quick analysis configuration
- A user profile can be created on a basis of a predefined profile

User API

- Rich set of user API for collection control, events highlighting, code instrumentation, and visualization enhancing.

Data Collectors and Analysis Types

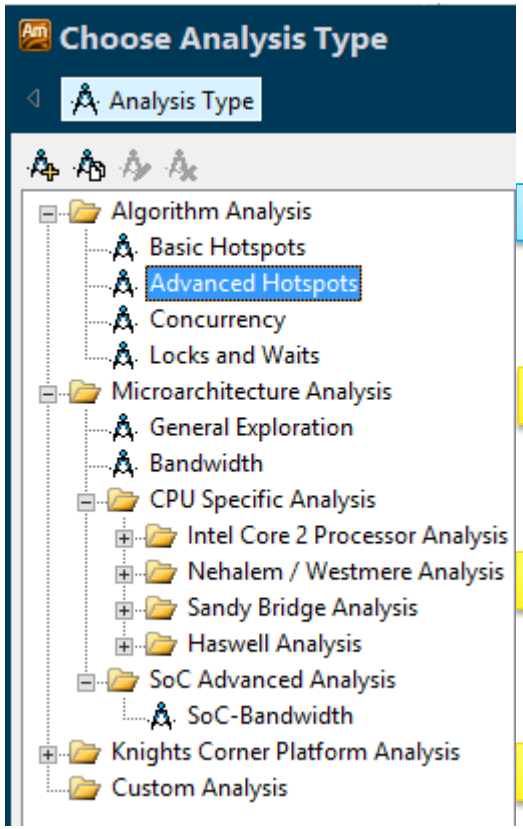
Intel® VTune™ Amplifier XE

Analysis Types (based on technology)

Software Collector Any x86 processor, any virtual, no driver	Hardware Collector Higher res., lower overhead, system wide
Basic Hotspots Which functions use the most time?	**Advanced Hotspots** Which functions use the most time? Where to inline? – Statistical call counts
Concurrency Tune parallelism. Colors show number of cores used.	**General Exploration** Where is the biggest opportunity? Cache misses? Branch mispredictions?
Locks and Waits Tune the #1 cause of slow threaded performance – waiting with idle cores.	**Advanced Analysis** Dig deep to tune bandwidth, cache misses, access contention, etc.

Intel® VTune™ Amplifier XE

Pre-defined Analysis Types



Advanced Hotspot analysis based on the underlying architecture

User mode sampling, Threading, IO, Signaling API instrumentation

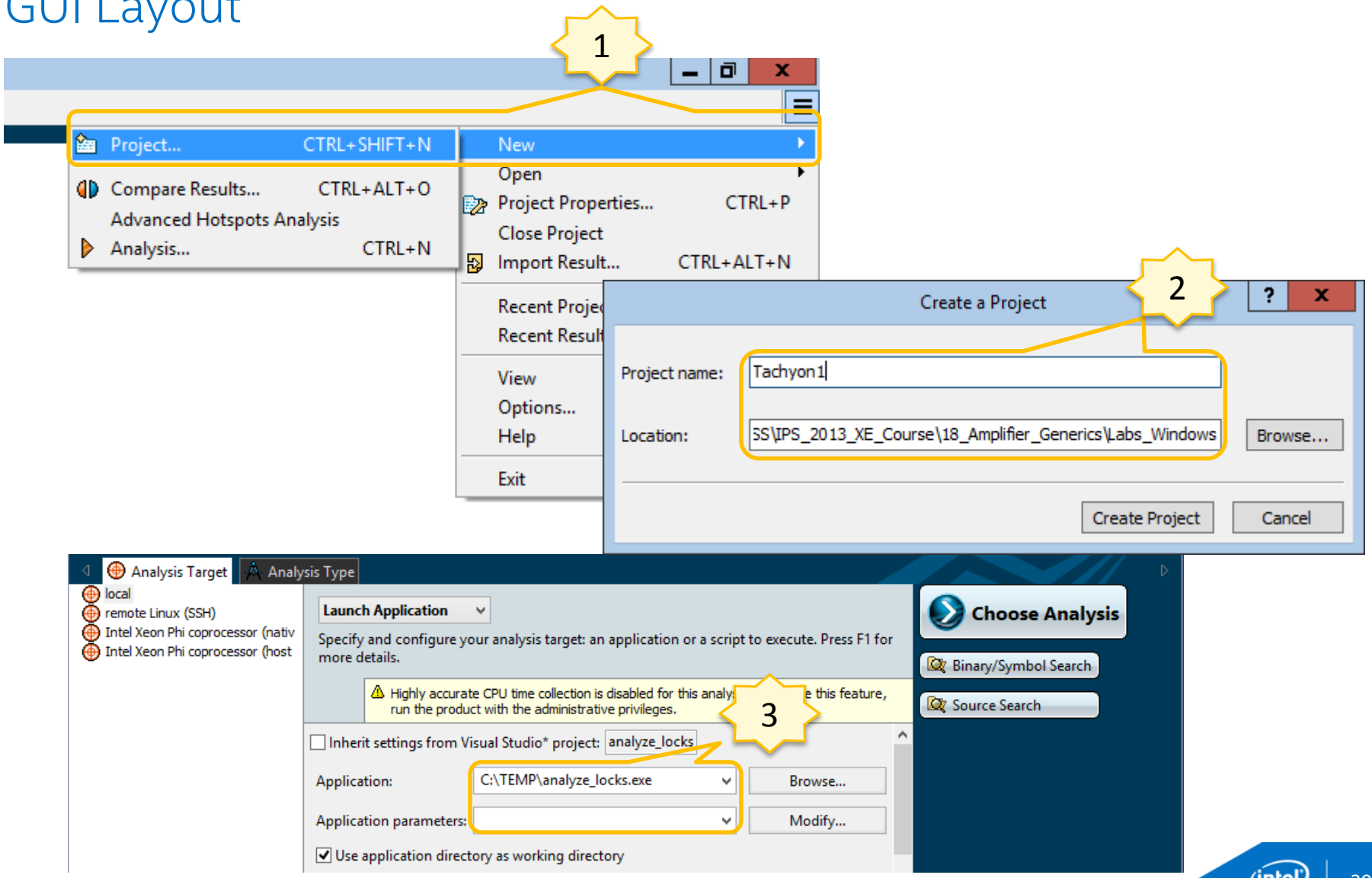
3rd Generation Core Architecture (a.k.a SandyBridge) analysis types

4th Generation Core Architecture (a.k.a Haswell) analysis types

GUI Layout

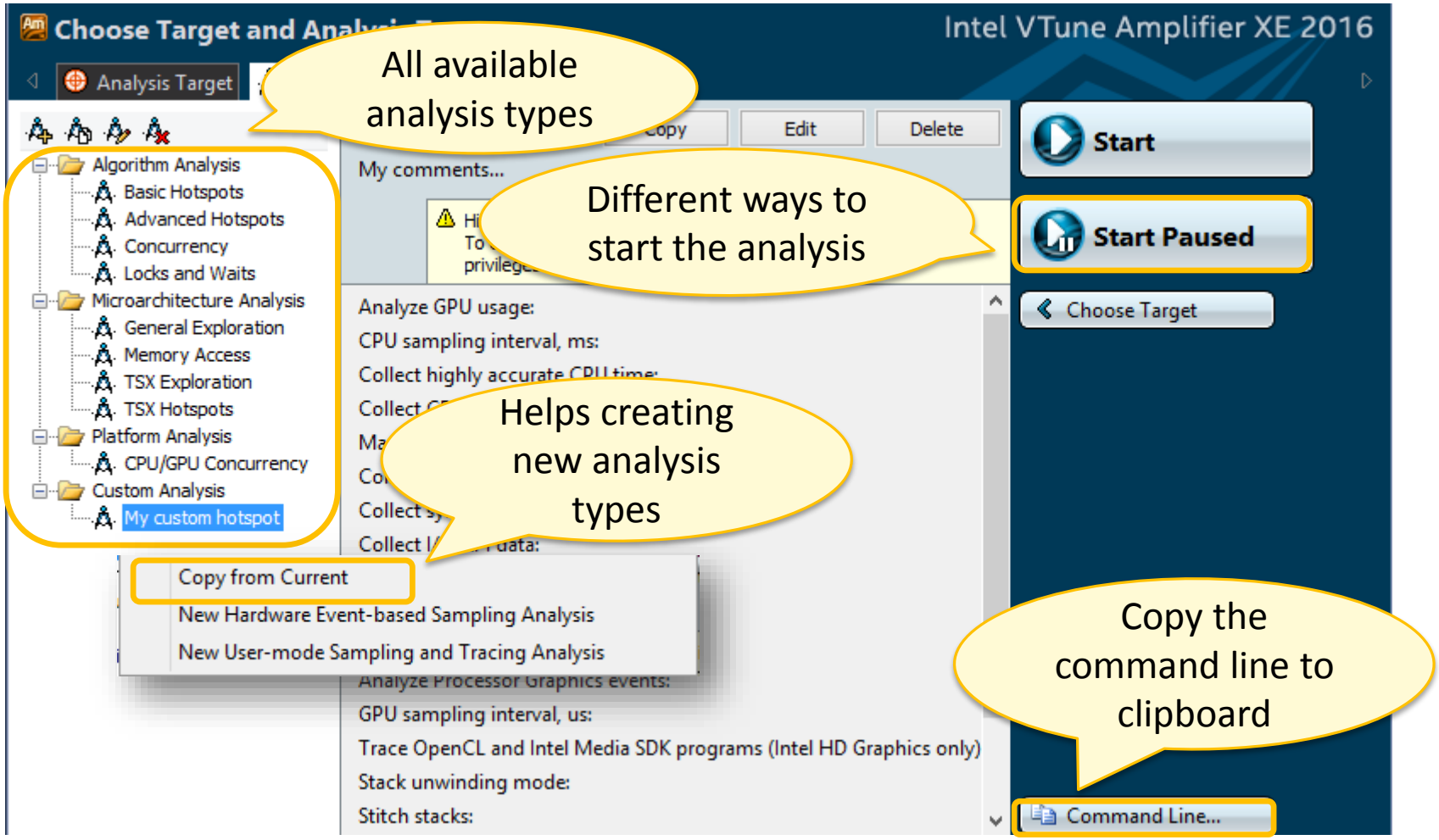
Creating a Project

GUI Layout



Selecting type of data collection

GUI Layout



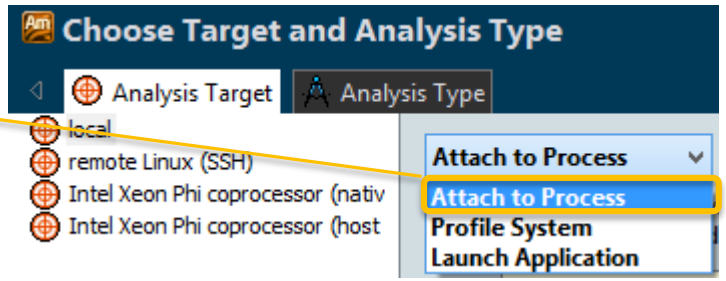
Profile a Running Application

No need to stop and re-launch the app when profiling

Two Techniques:

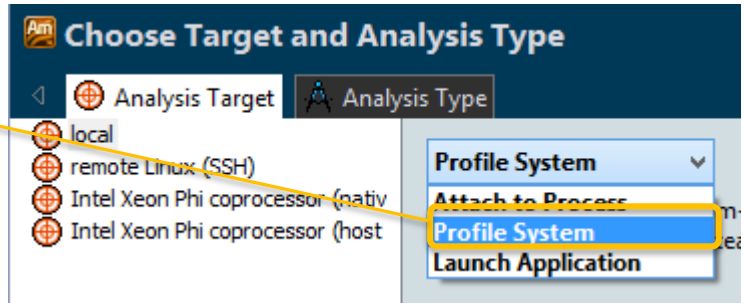
Attach to Process:

- Any type of analysis



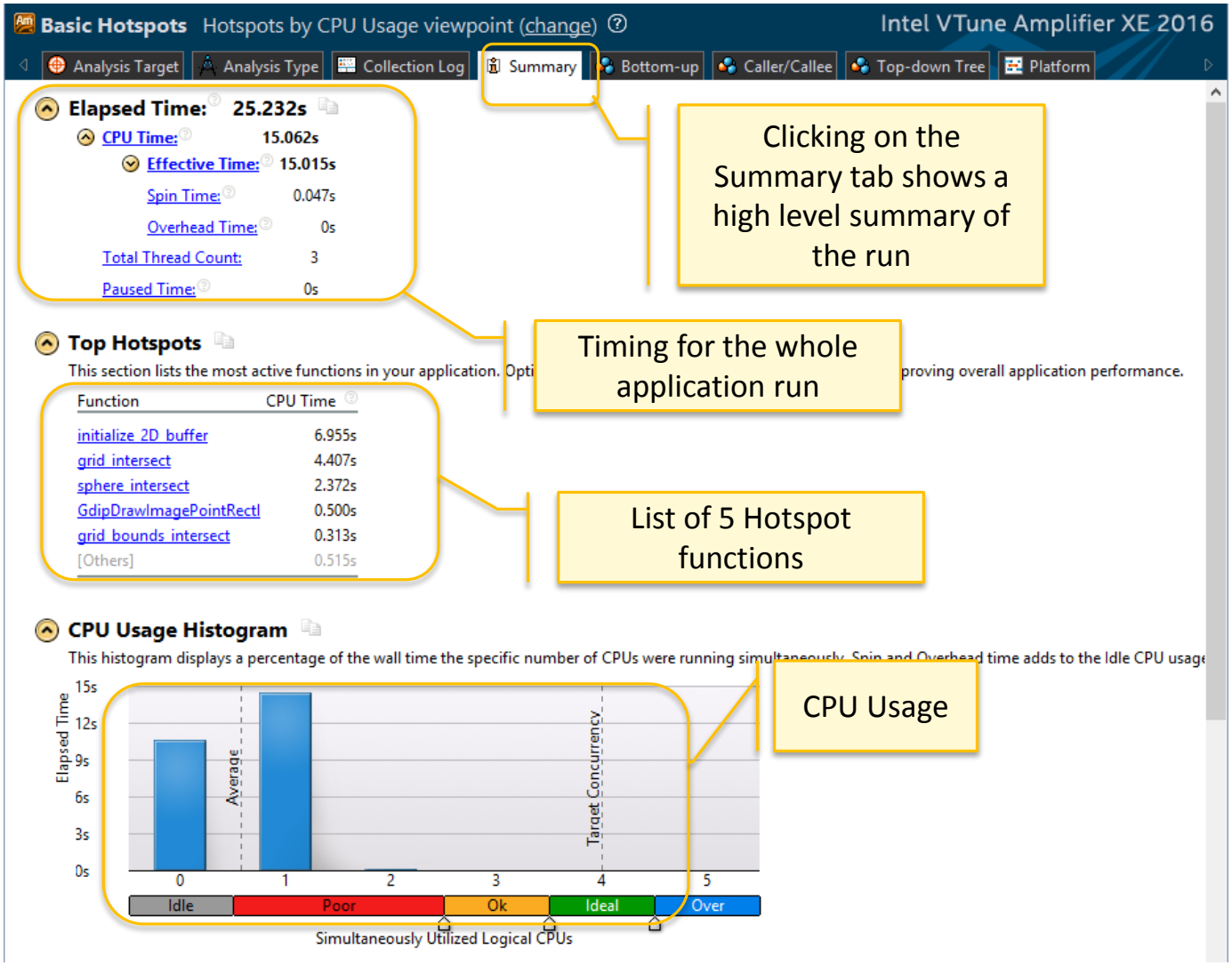
Profile System:

- Advanced Hotspots & Custom EBS
- Optional: Filter by process after collection



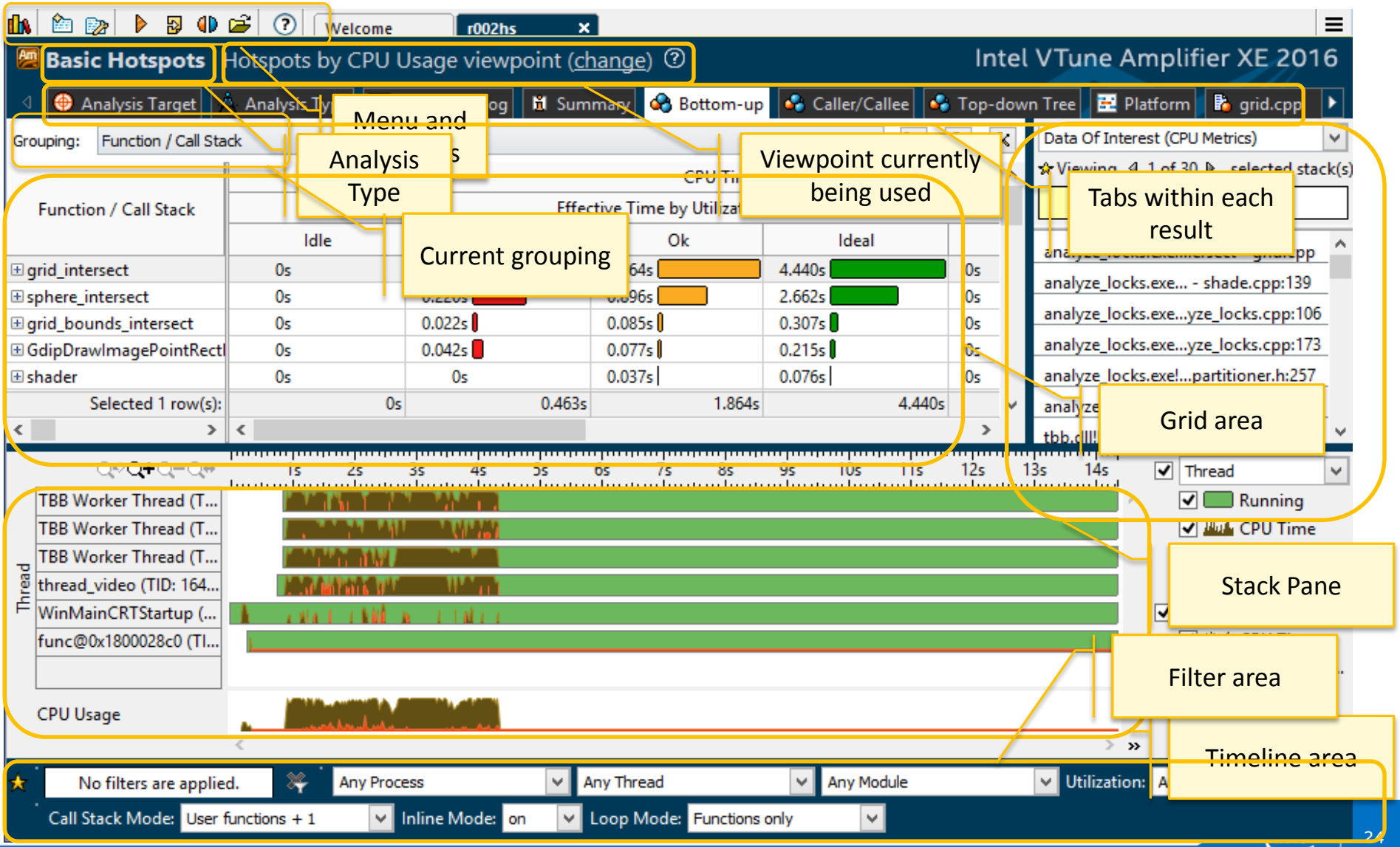
Summary View

GUI Layout



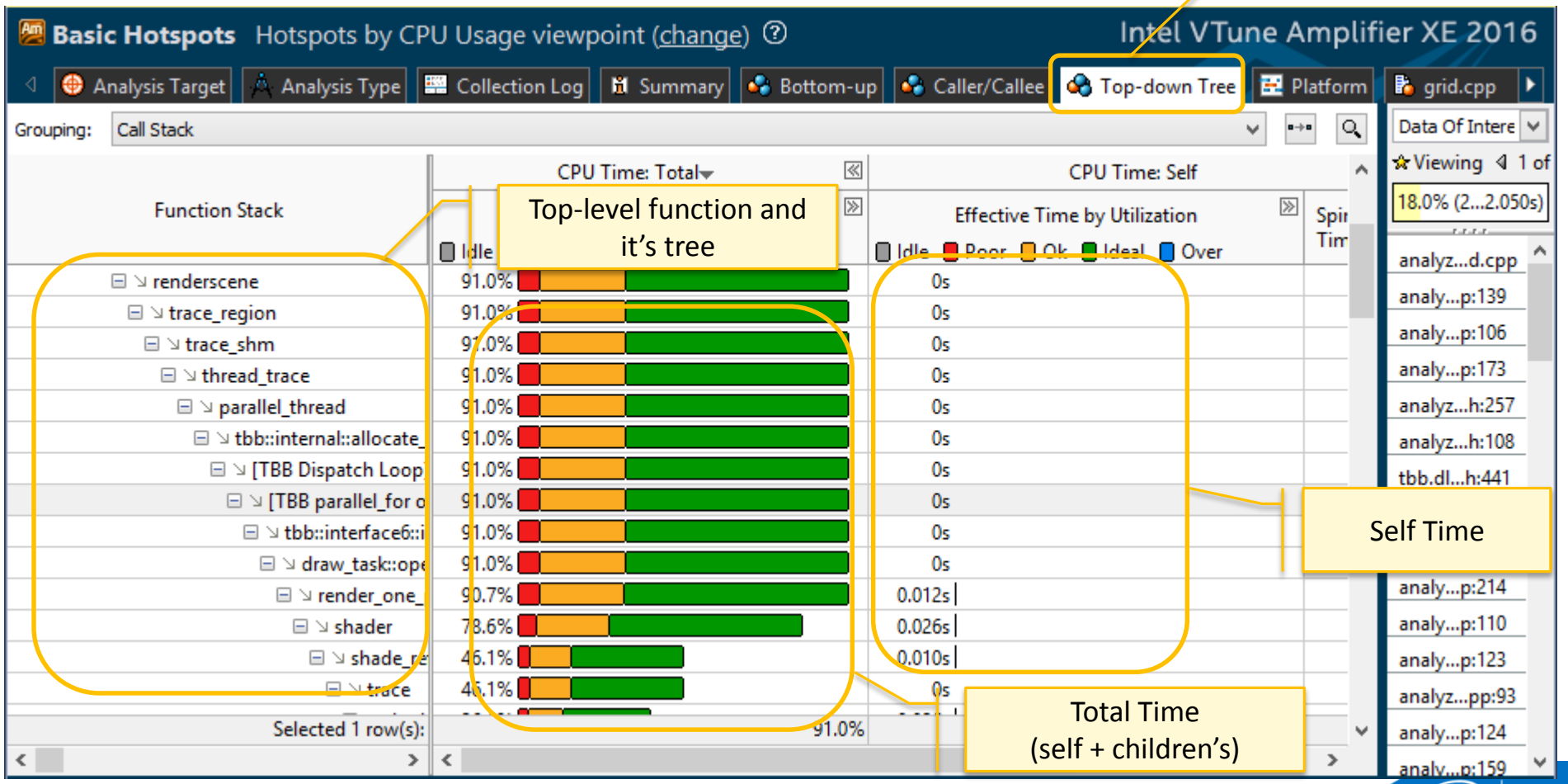
Bottom-Up View

GUI Layout



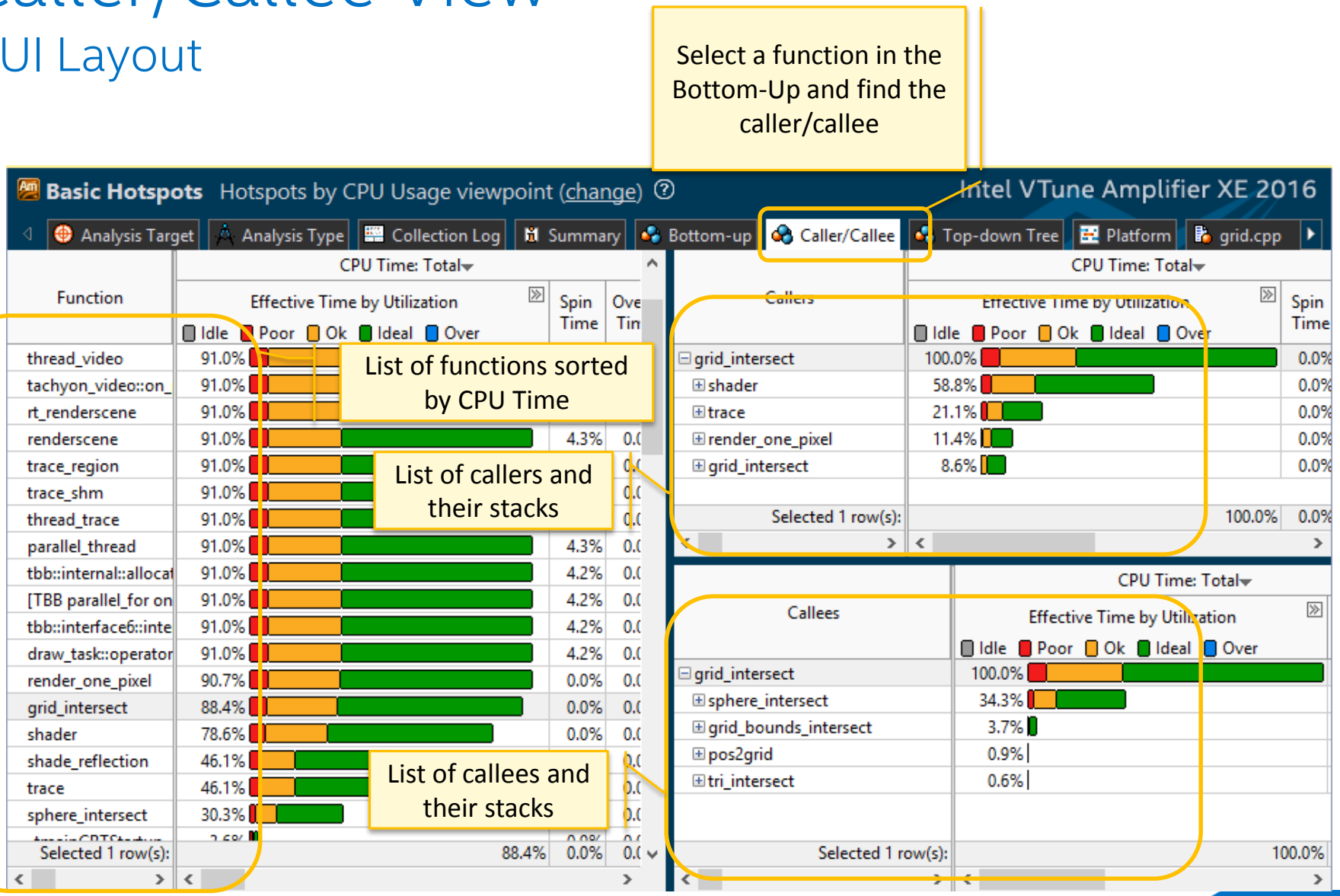
Top-Down View

GUI Layout



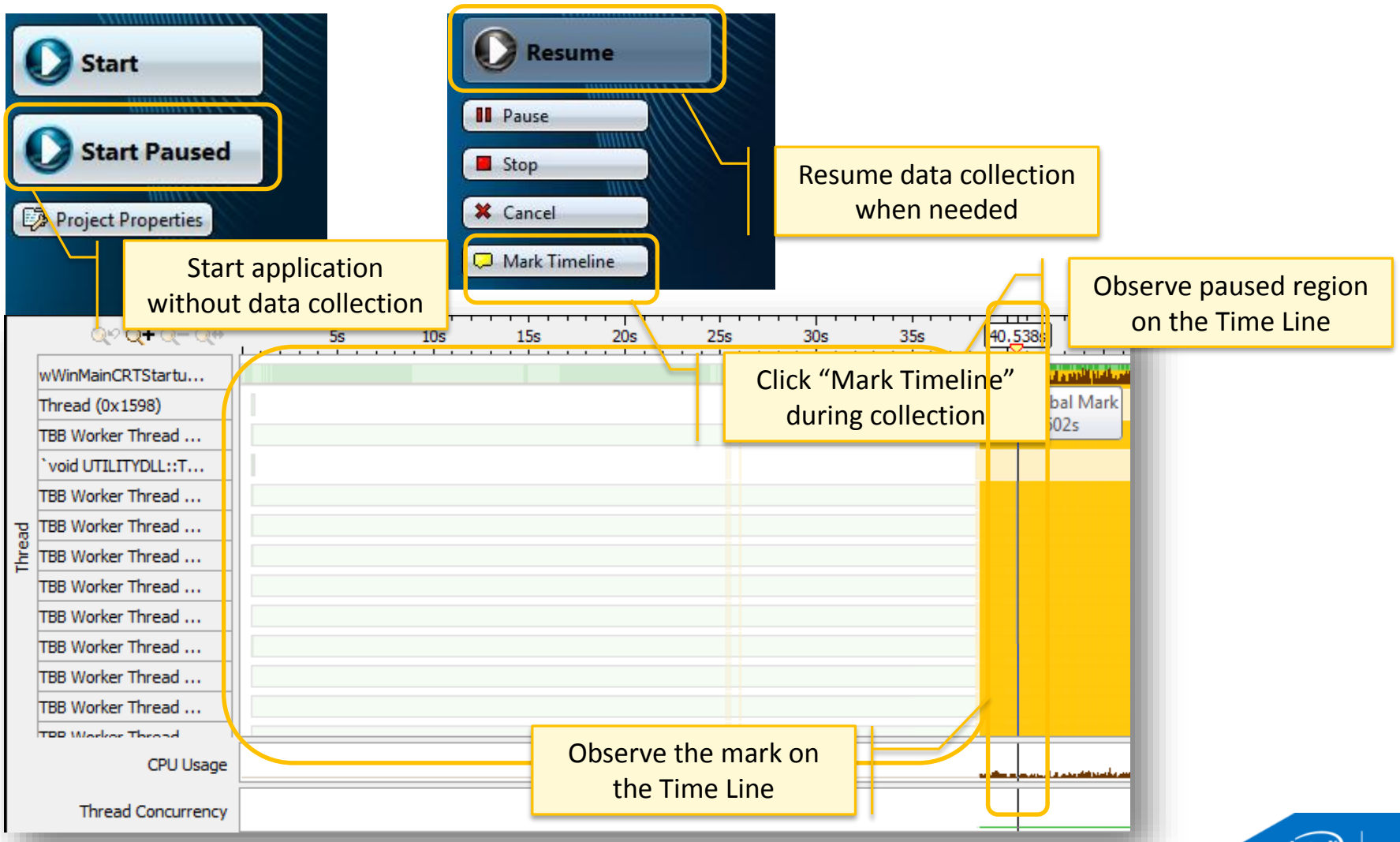
Caller/Callee View

GUI Layout



Adding User Marks to the Timeline

GUI Controls

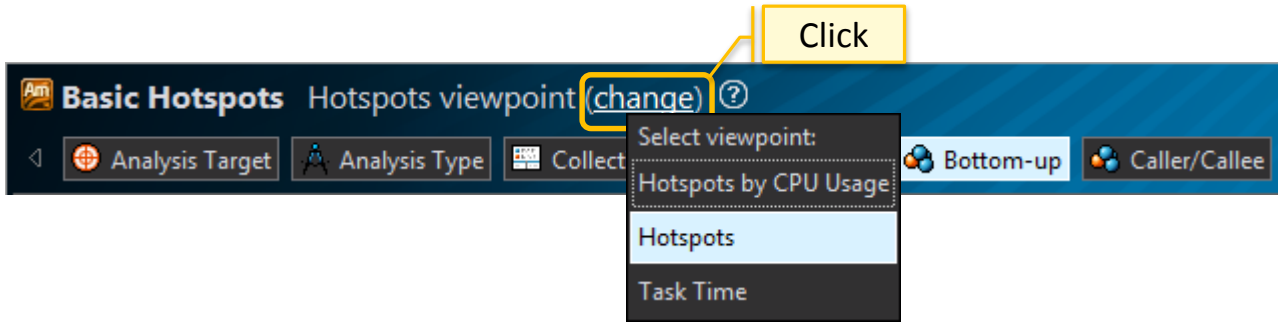


Key Result Analysis and
GUI Concepts

Result Analysis
GUI Concepts

Viewpoints

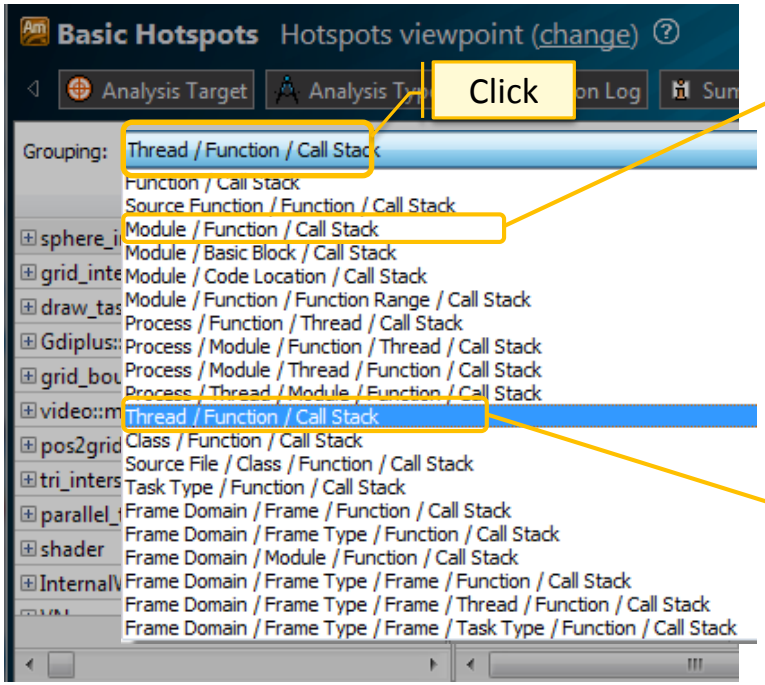
- It is a pre-defined view that determines what needs to be displayed in the grid and timeline for a given analysis type
- An analysis type may support more than one view points
- To change viewpoints, select a viewpoint by clicking on

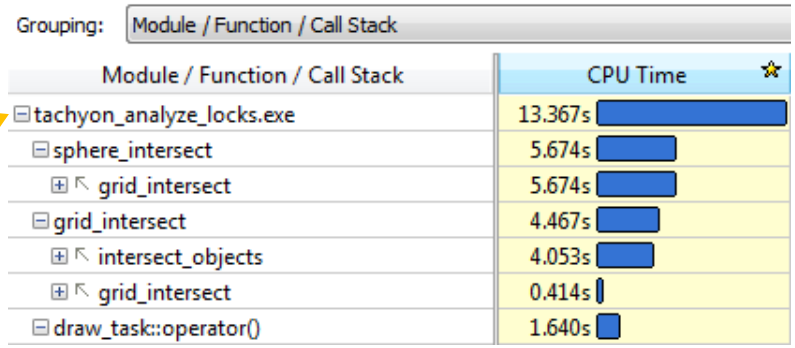


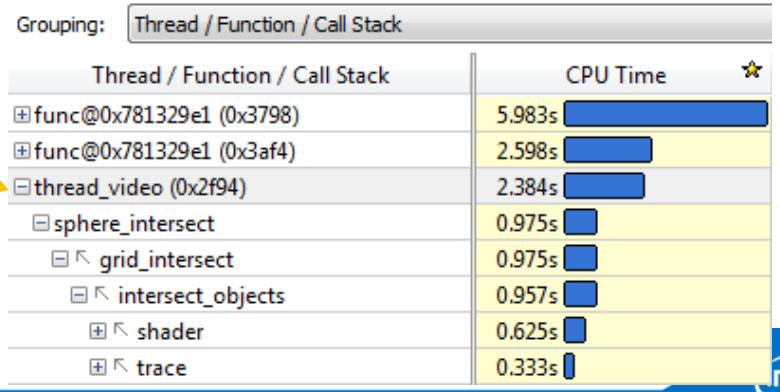
Result Analysis
GUI Concepts

Groupings

- Each analysis type has many viewpoints
- Each viewpoint has pre-defined groupings
- Allows you to analyze the data in different hierarchies and granularities

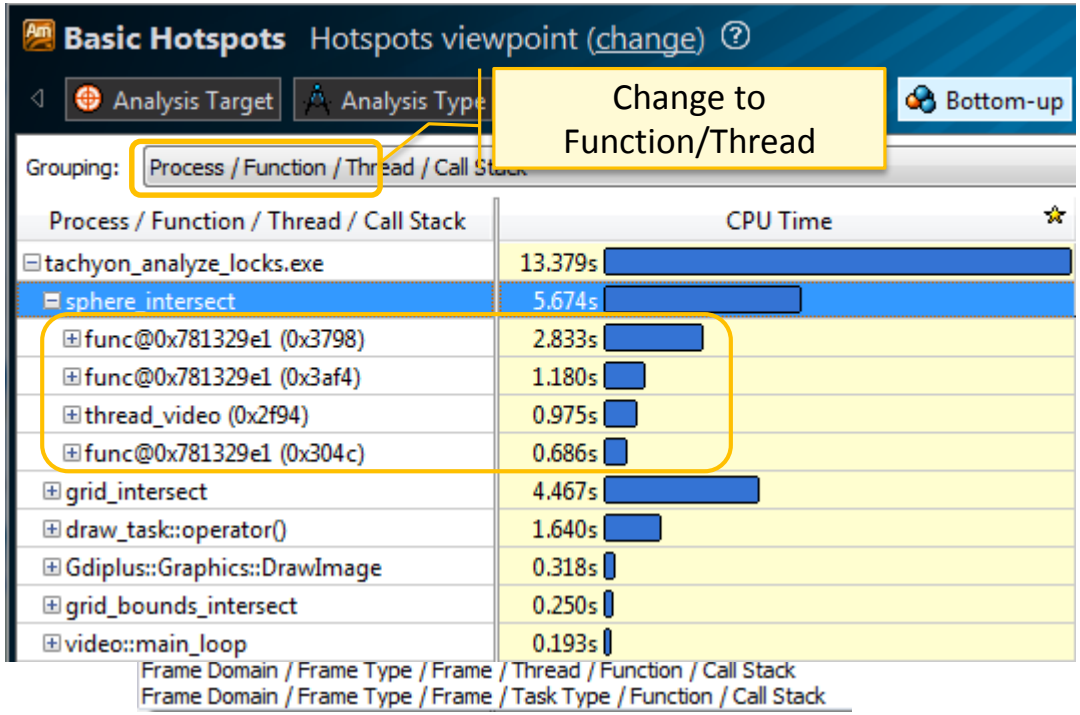






Viewpoints and Groupings

For example, pre-defined groupings can be used to determine load imbalance



Key Concepts
Results Comparison

VTune™ Amplifier XE allows comparison of two similar runs

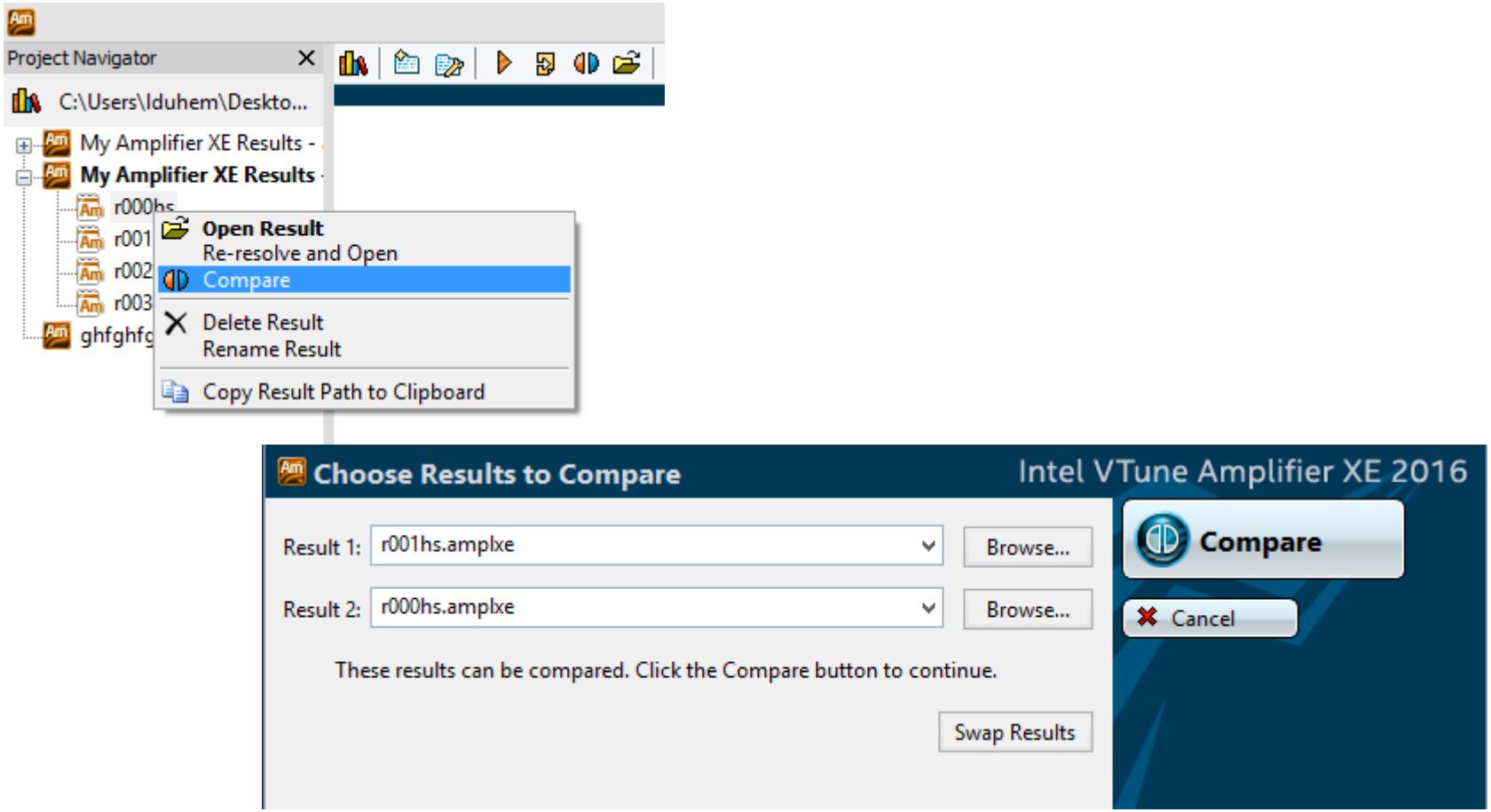
Extremely useful for:

- Benchmarking
- Regression analysis
- Testing

During performance optimization work source code may change

- Binary recompiled: compare based on source function
- Inside a function: compare based on functions level
- Functions changed: group by source files and compare
- Source files changed: compare by modules

Results Comparison



Reminding the methodology
of performance profiling and tuning

The Goal: minimize the time it takes your program / module / function to execute

- Identify Hotspots and focus on them
- It's just a few functions (20% of code does 80% of job)
- Optimize them (with compiler or hand optimizations)
- Check for hotspots again, and find new ones

How to optimize the Hotspots?

- Maximize CPU utilization and minimize elapsed time
- Ensure CPU is busy all the time
- All Cores busy – parallelism
- Busy with useful tasks
- Optimize tasks execution

Performance profiling
Terminology

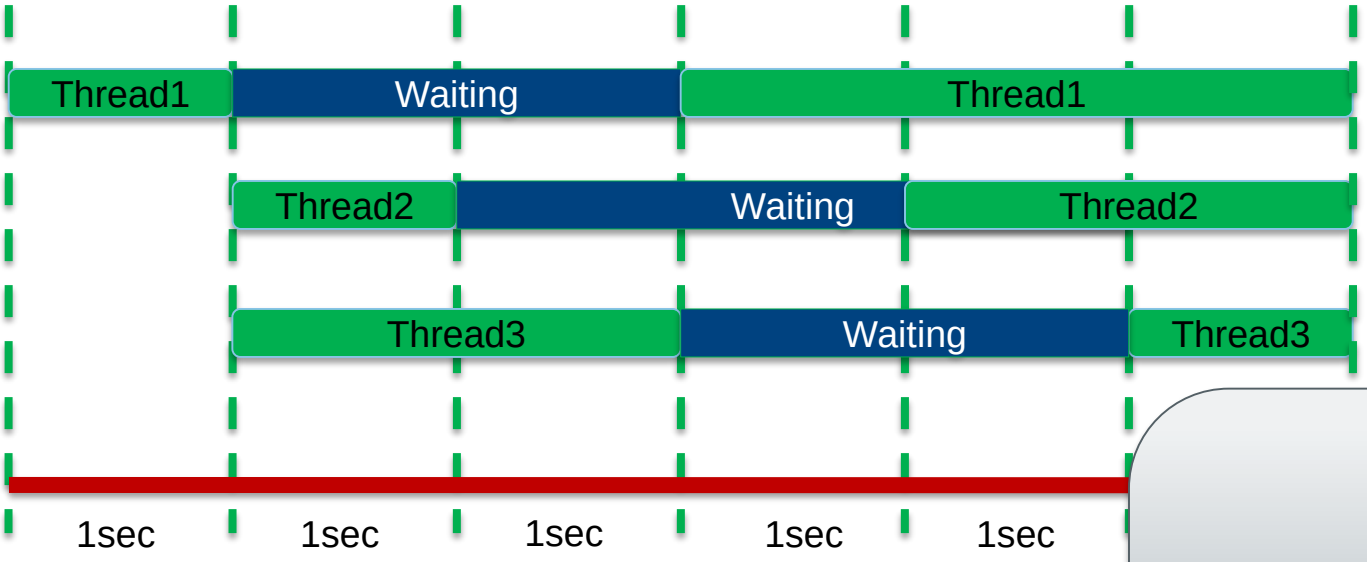
Elapsed Time
The total time your target application ran. Wall clock time at end of application – Wall clock time at start of application

CPU Time
The amount of time a thread spends executing on a logical processor. For multiple threads, the CPU time of the threads is summed.

Wait Time
The amount of time that a given thread waited for some event to occur, such as: synchronization waits and I/O waits

Performance profiling

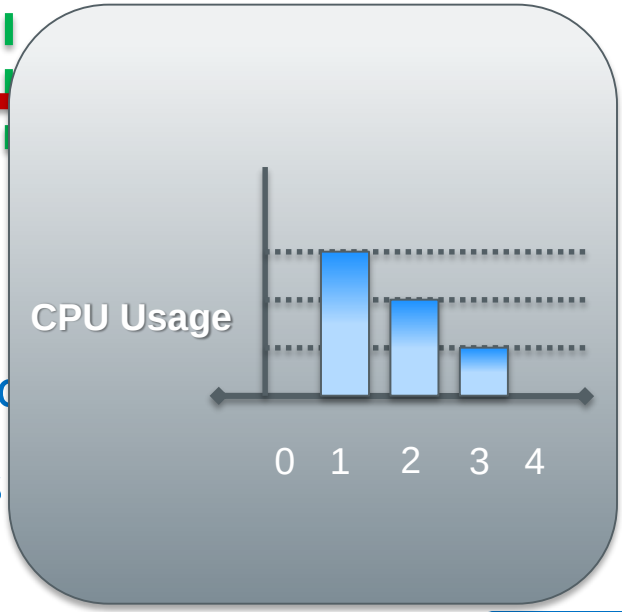
CPU Usage



Elapsed Time: 6 seconds

CPU Time: T1 (4s) + T2 (3s) + T3 (3s) = 10 secon

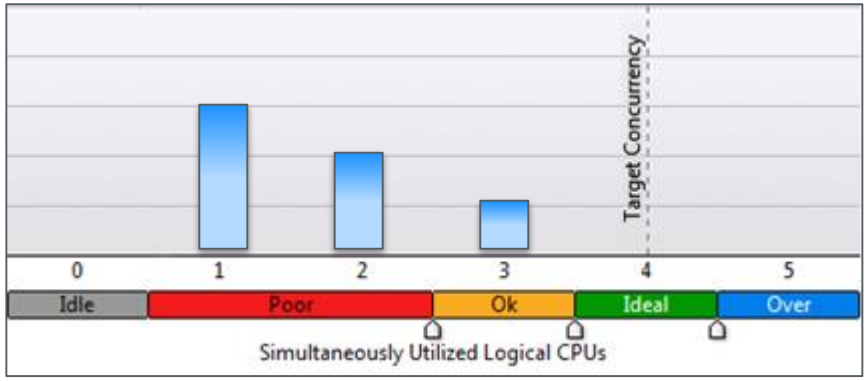
Wait Time: T1(2s) + T2(2s) + T3 (2s) = 6 seconds



CPU Usage

How it's presented by VTune Amplifier

Summary View: CPU Usage Histogram



Only CPU Time measured

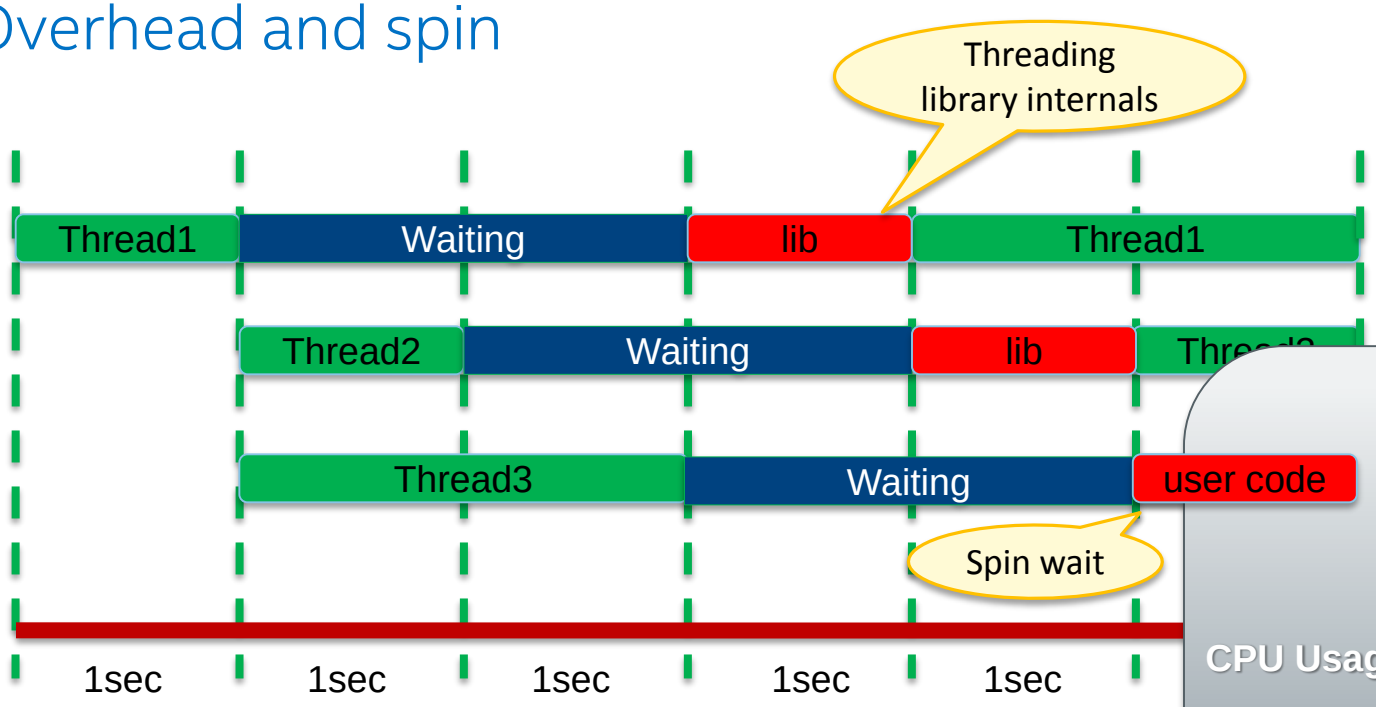
Wait Time is not counted in Hotspots

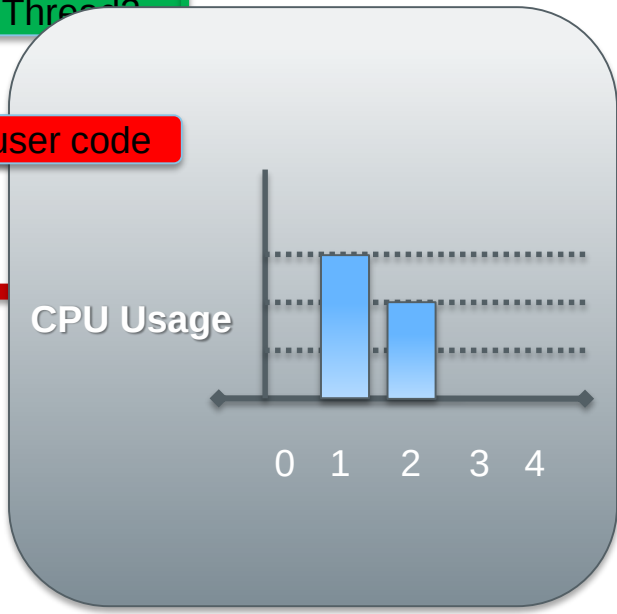
Bottom-Up View: CPU Time

Function	CPU Time	By CPU Utilization
My_Func()	10 s	

Performance profiling

Overhead and spin





Elapsed Time: 6 seconds

CPU Time: T1 (4s) + T2 (3s) + T3 (3s) = 10 seconds

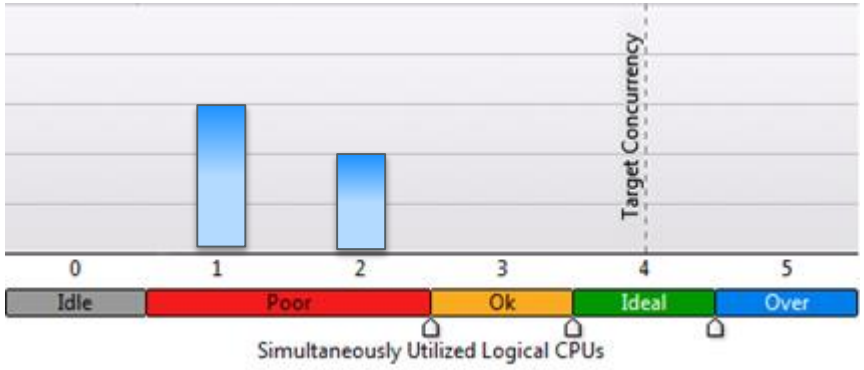
Wait Time: T1(2s) + T2(2s) + T3 (2s) = 6 seconds

Overhead and spin Time: T1(1s) + T2(1s) + T2(1s) = 3 s

CPU Usage

How it's presented by VTune Amplifier

Summary View: CPU Usage Histogram



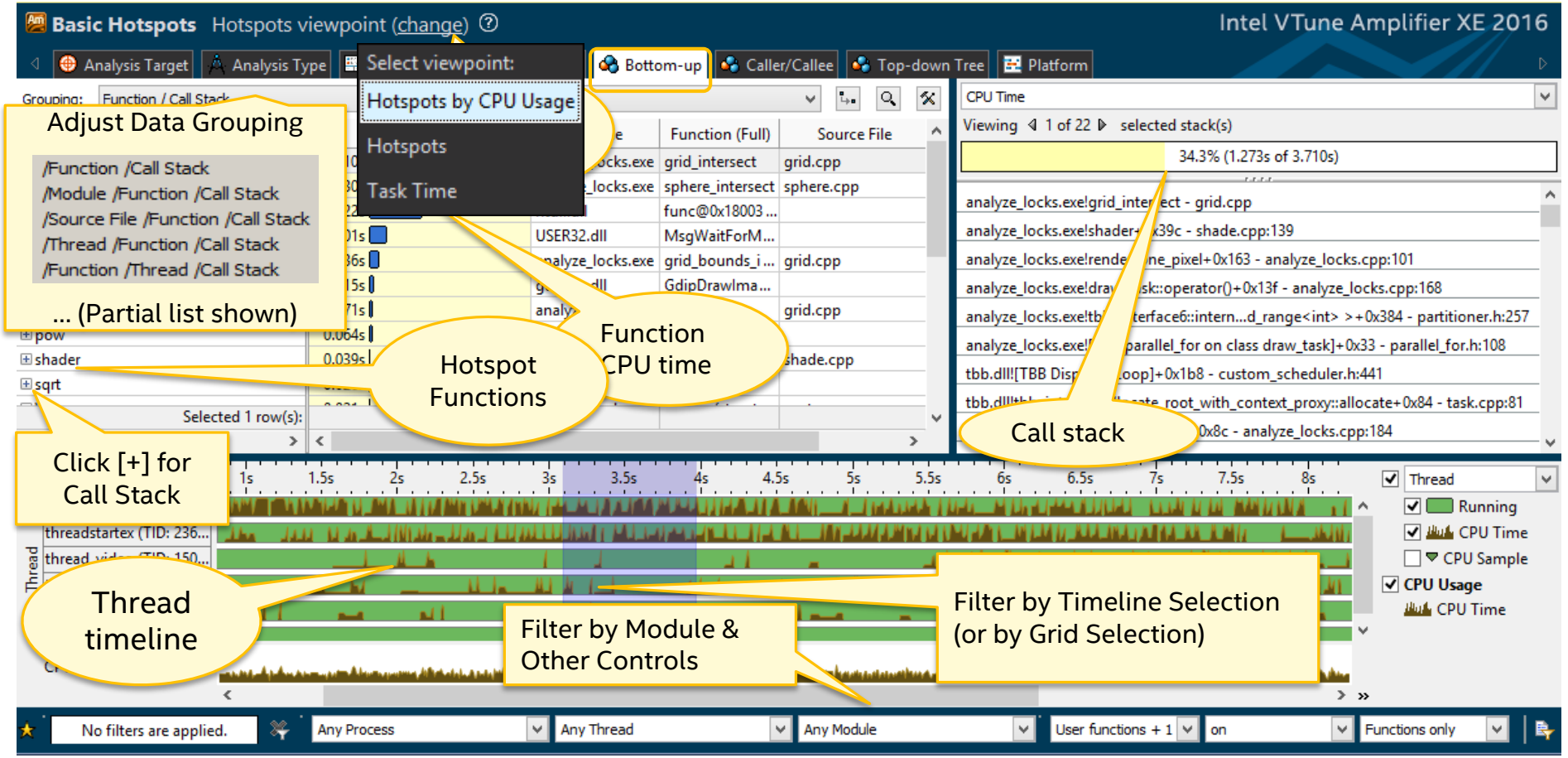
Overhead and Spin Time is not counted for CPU Usage

Bottom-Up View: CPU Time

Function	CPU Time	By CPU Utilization	Overhead and Spin Time
My_Func()	10 s		4 s

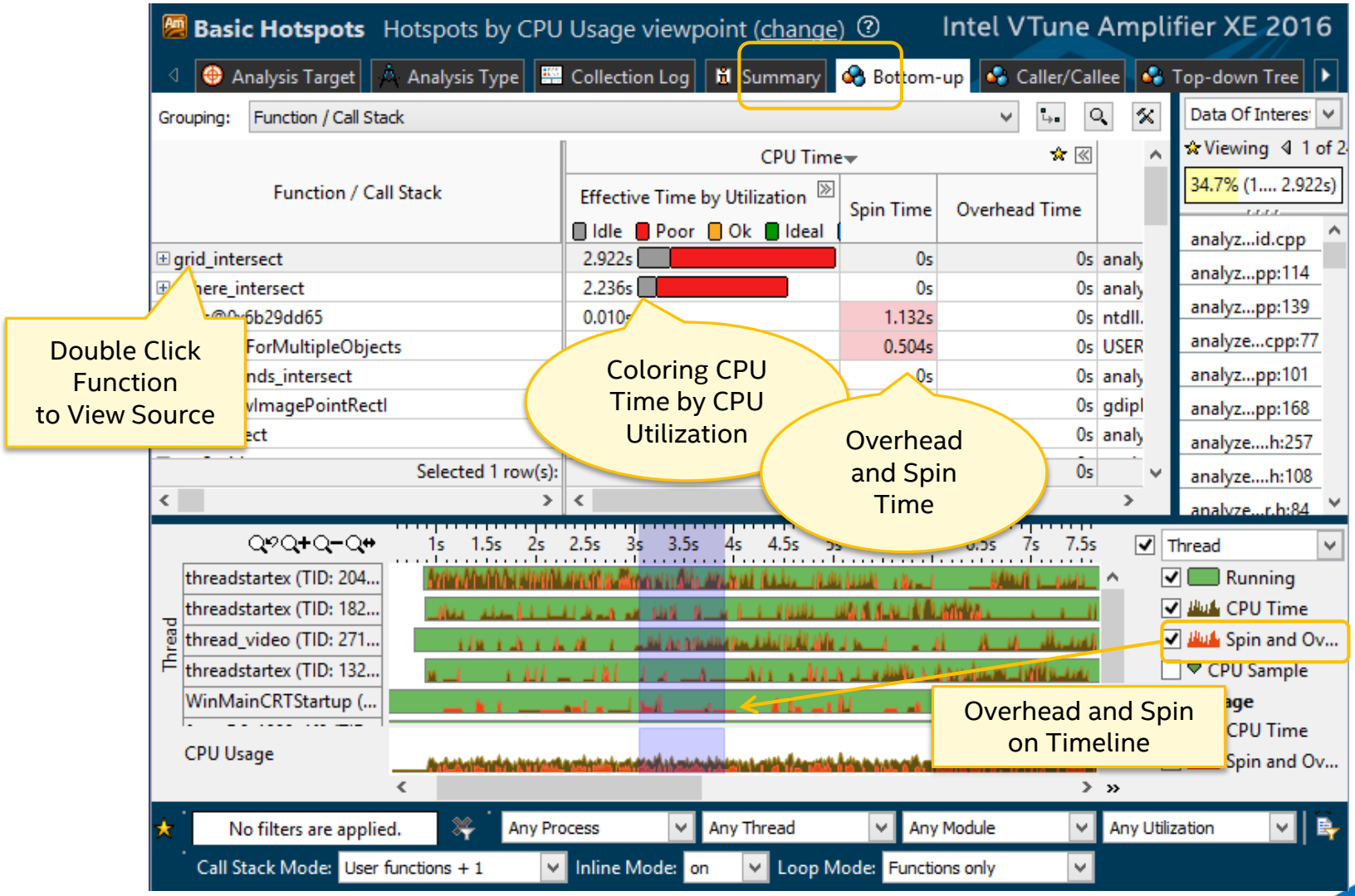
Hotspots analysis

Hotspot viewpoint



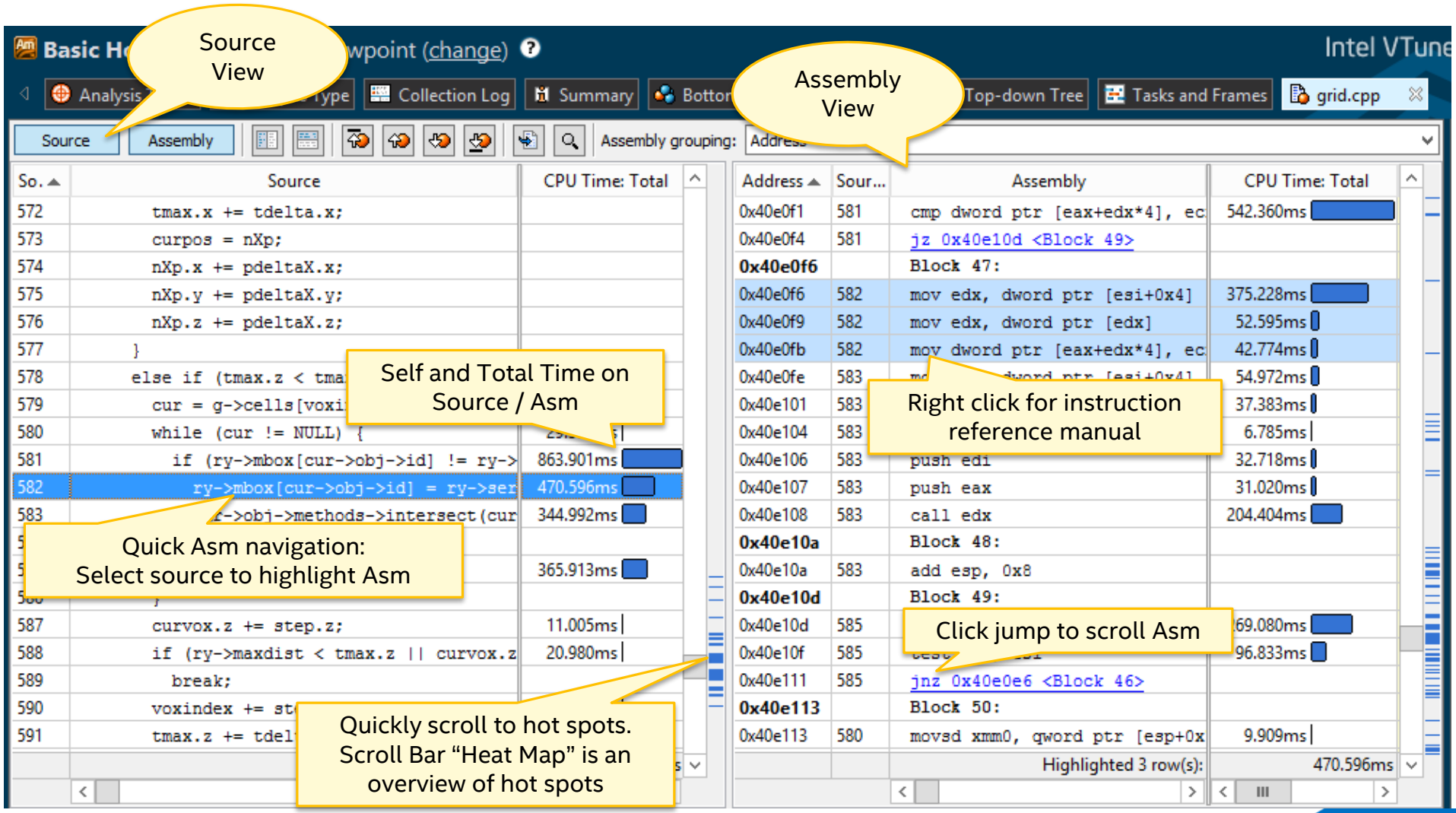
Hotspots analysis

Hotspot functions by CPU usage



Hotspots analysis

Source View



Advanced Hotspot analysis

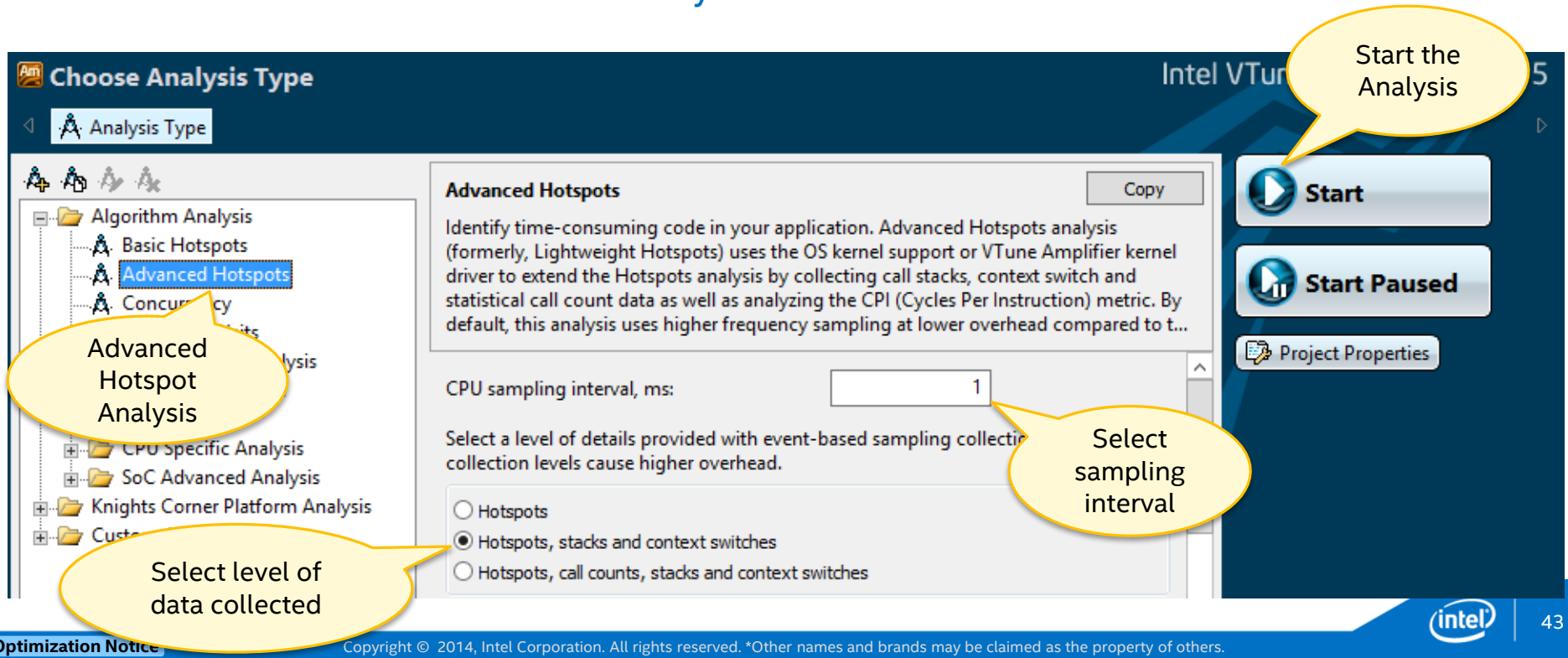
Uses Intel's CPU hardware performance collectors

Higher resolution of sampling (~1 /ms)

Capable for system wide analysis (all processes running in a system)

OS modules and drivers profiling (ring 0 level)

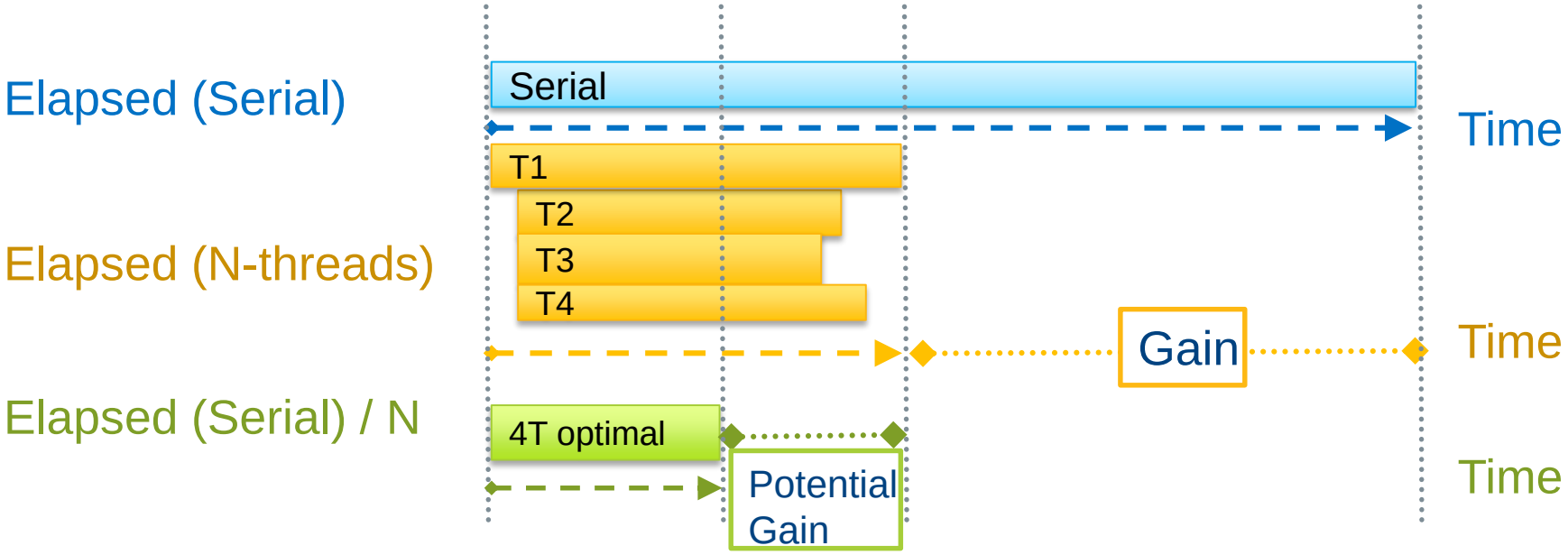
OS context switches and threads synchronization issues



Reminding methodology
of performance profiling and tuning

How to optimize the Hotspots?

- Maximize CPU utilization and minimize elapsed time
  - Ensure CPU is busy all the time
  - All Cores busy – parallelism (high concurrency)

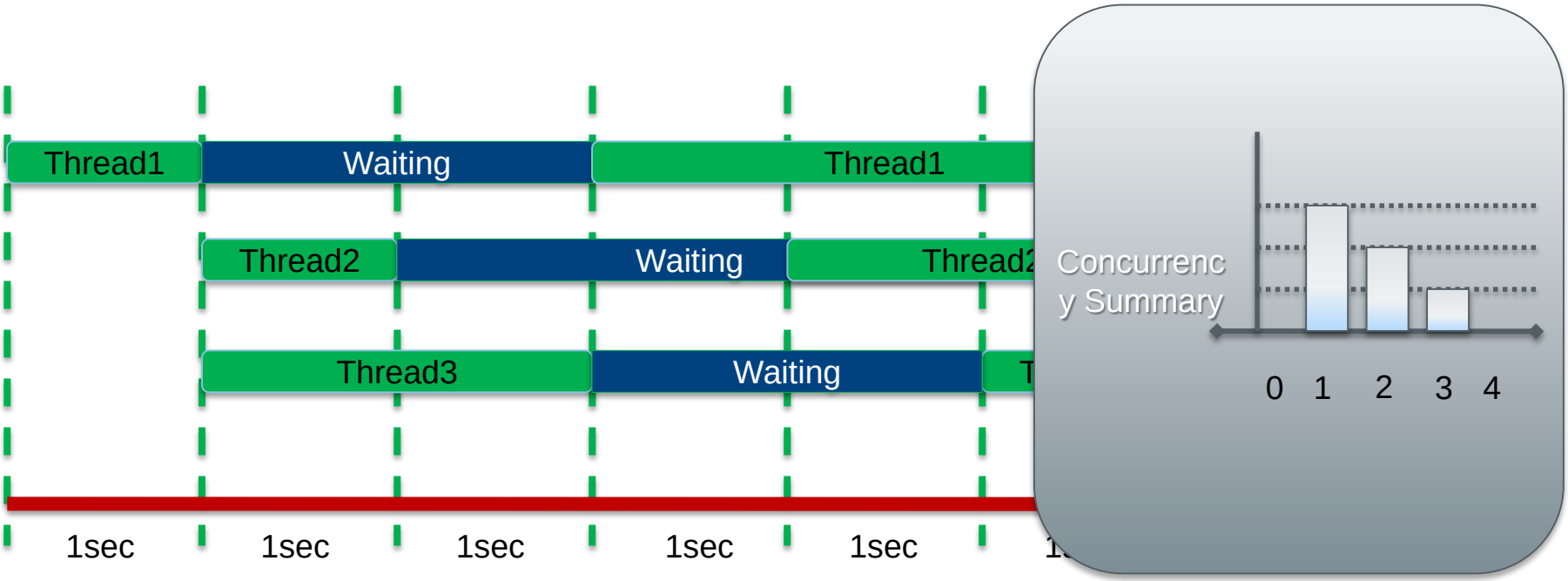


Performance profiling

Concurrency

Concurrency -

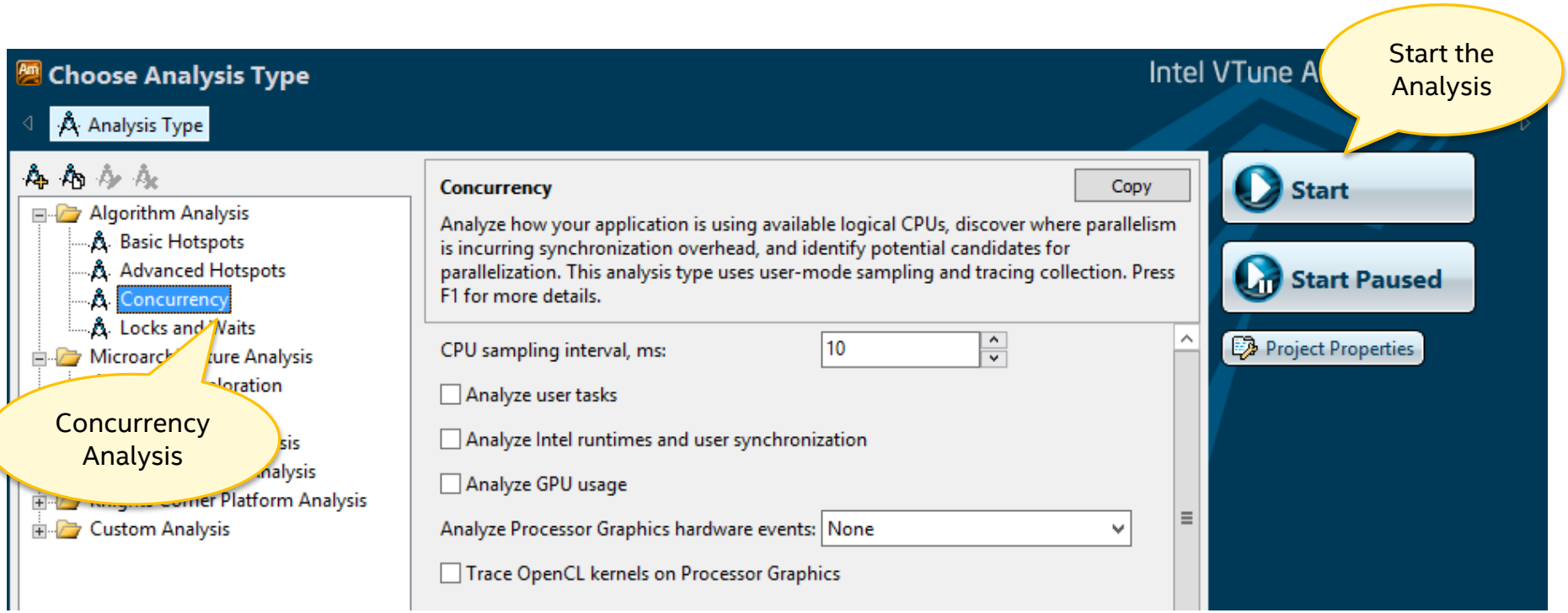
Is a measurement of the number of active threads



Parallelism/Concurrency Analysis

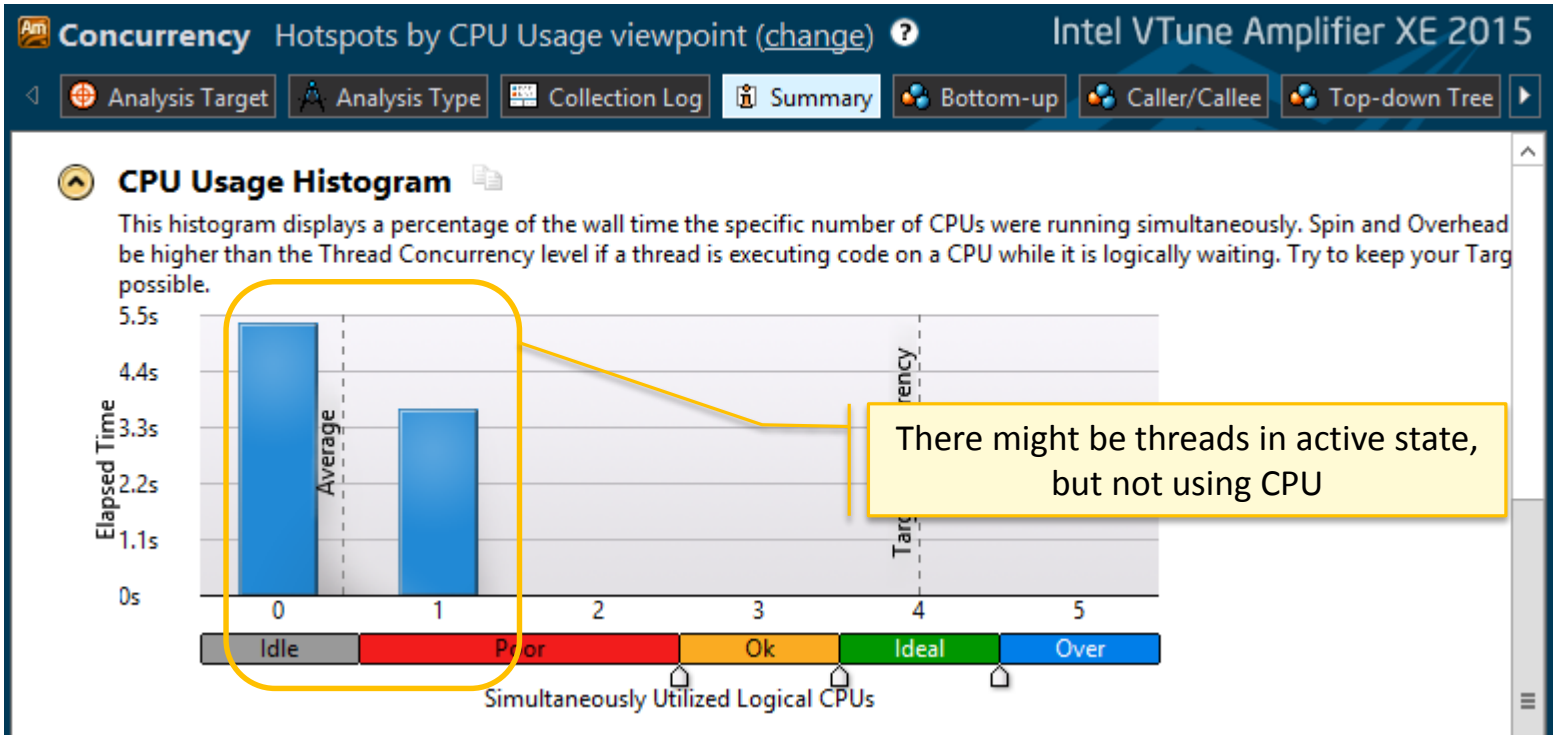
For Parallelism / Concurrency analysis,

- Stack sampling is done just like in Hotspots analysis
- Wait functions are instrumented (e.g. WaitForSingleObject, EnterCriticalSection)
- Signal functions are instrumented (e.g. SetEvent, LeaveCriticalSection)
- I/O functions are instrumented (e.g. ReadFile, socket)



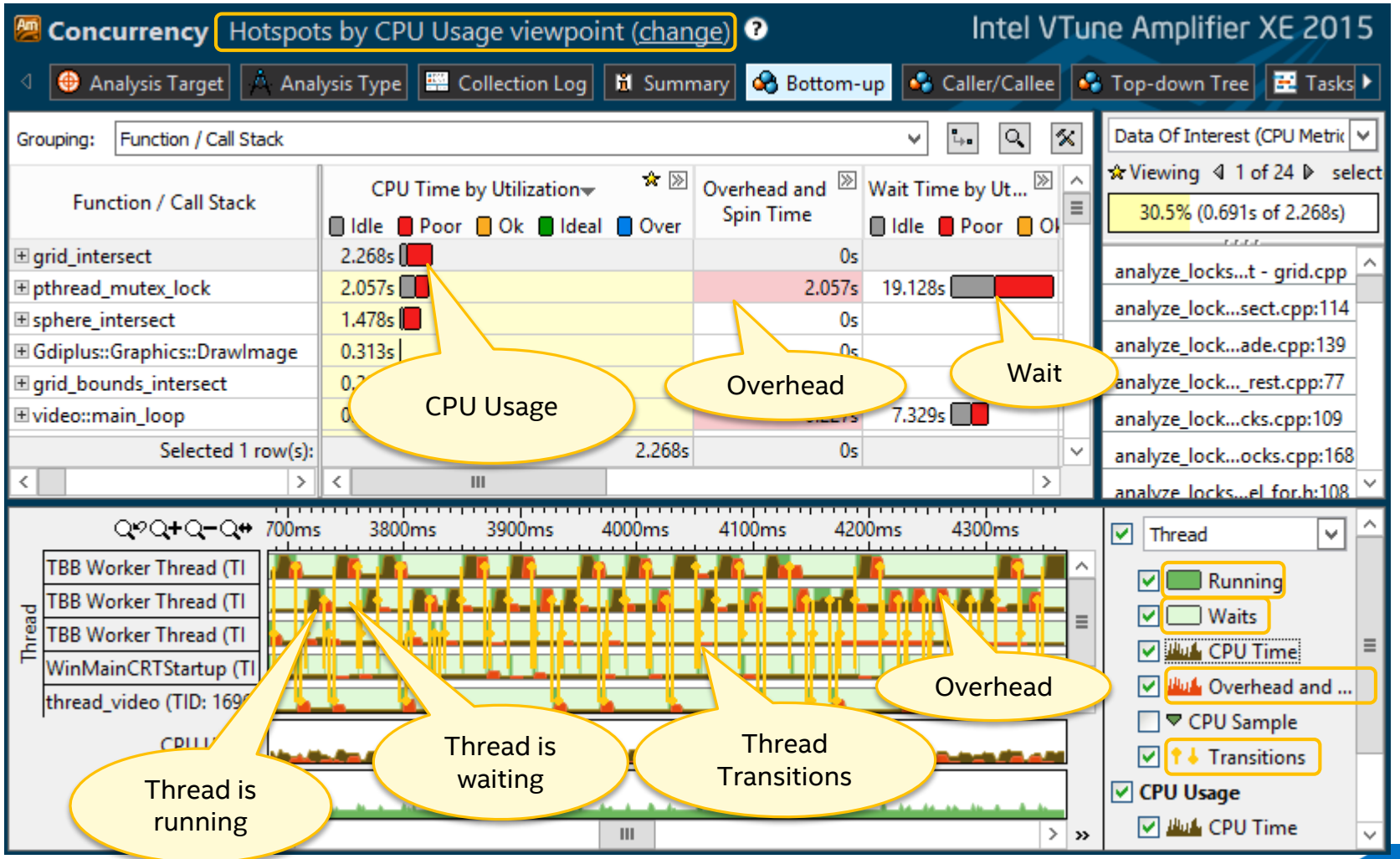
Concurrency Analysis

Summary view. CPU Usage Histogram



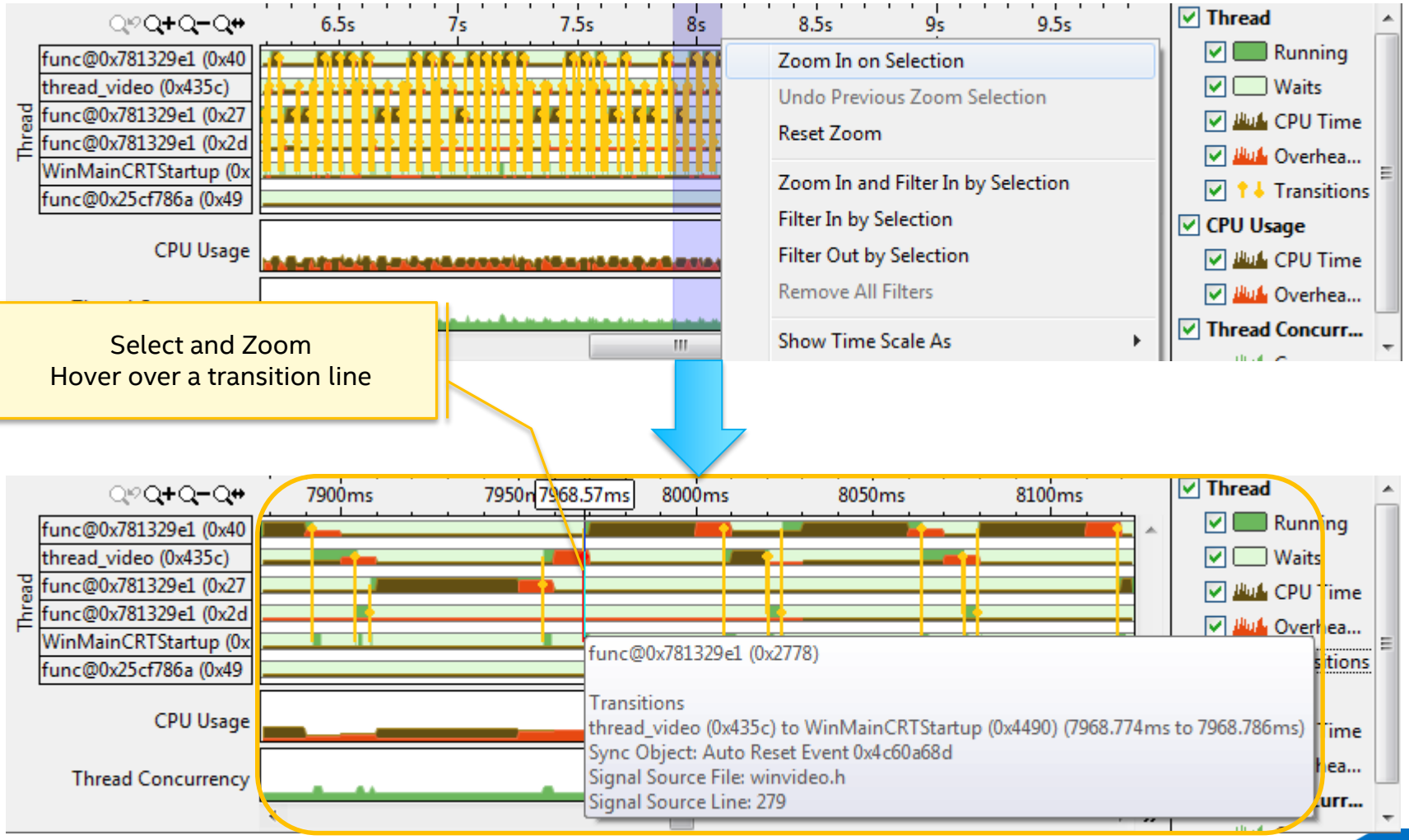
Concurrency Analysis

Bottom-Up view. CPU Usage



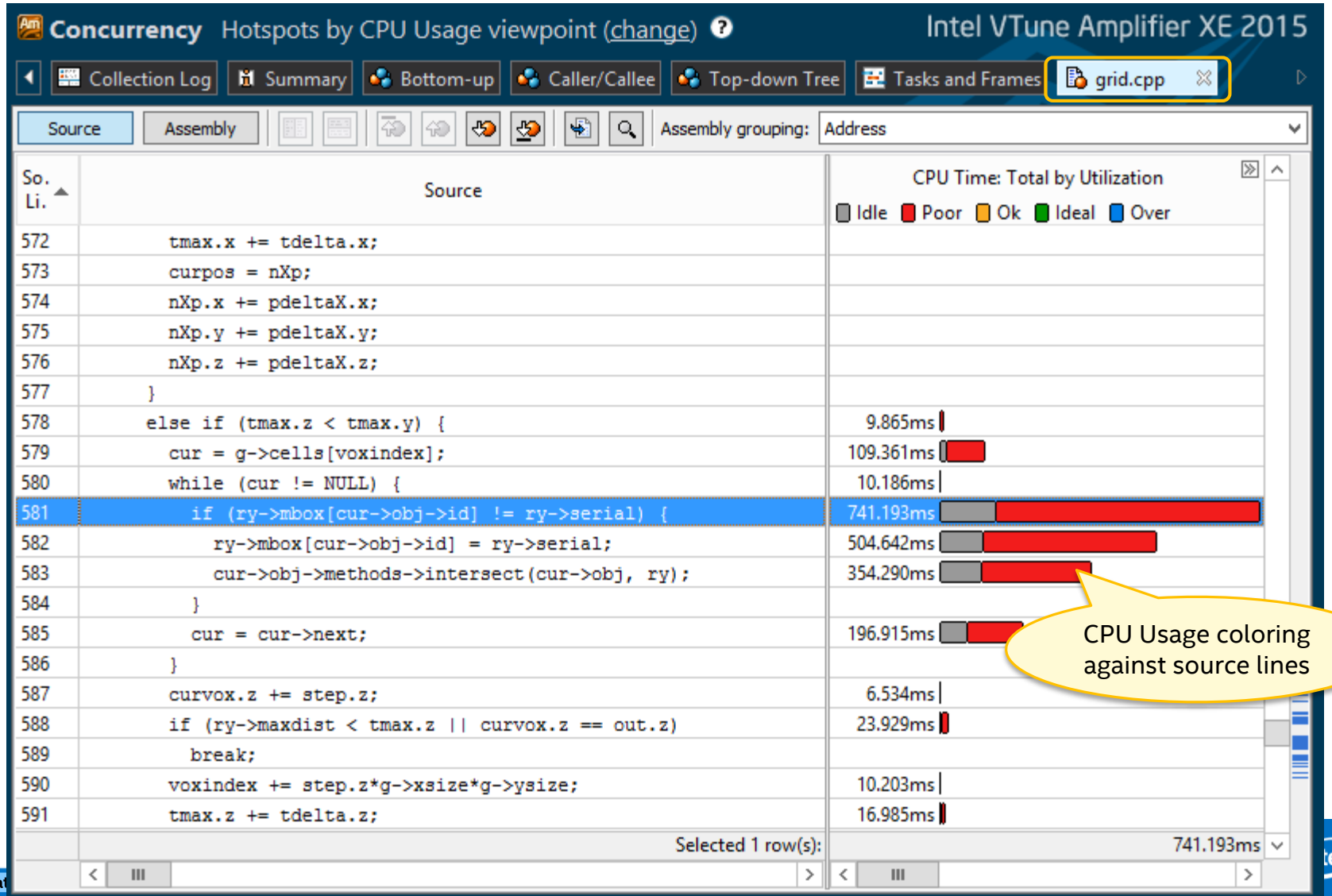
Concurrency Timeline

Investigate reasons for transitions



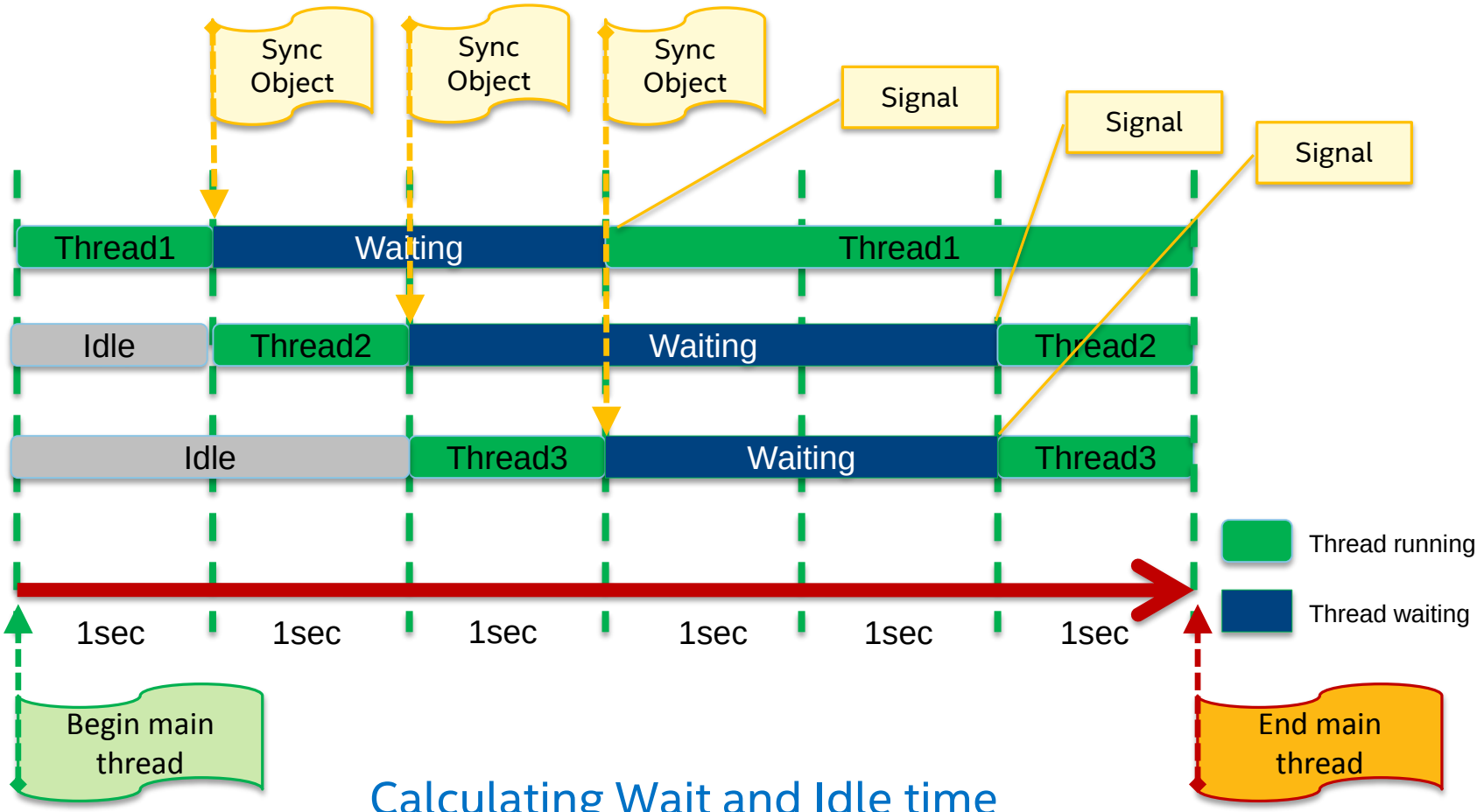
Concurrency Analysis

Source Code View



Performance profiling

Waiting on locks

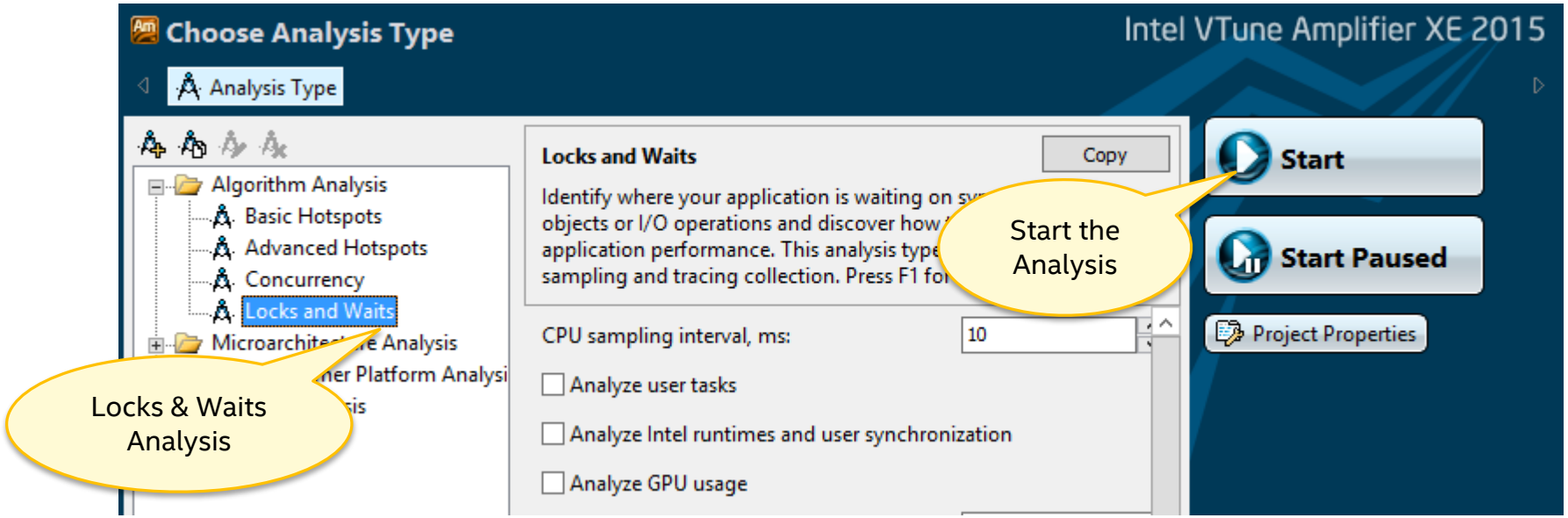


Calculating Wait and Idle time

Locks and Waits Analysis

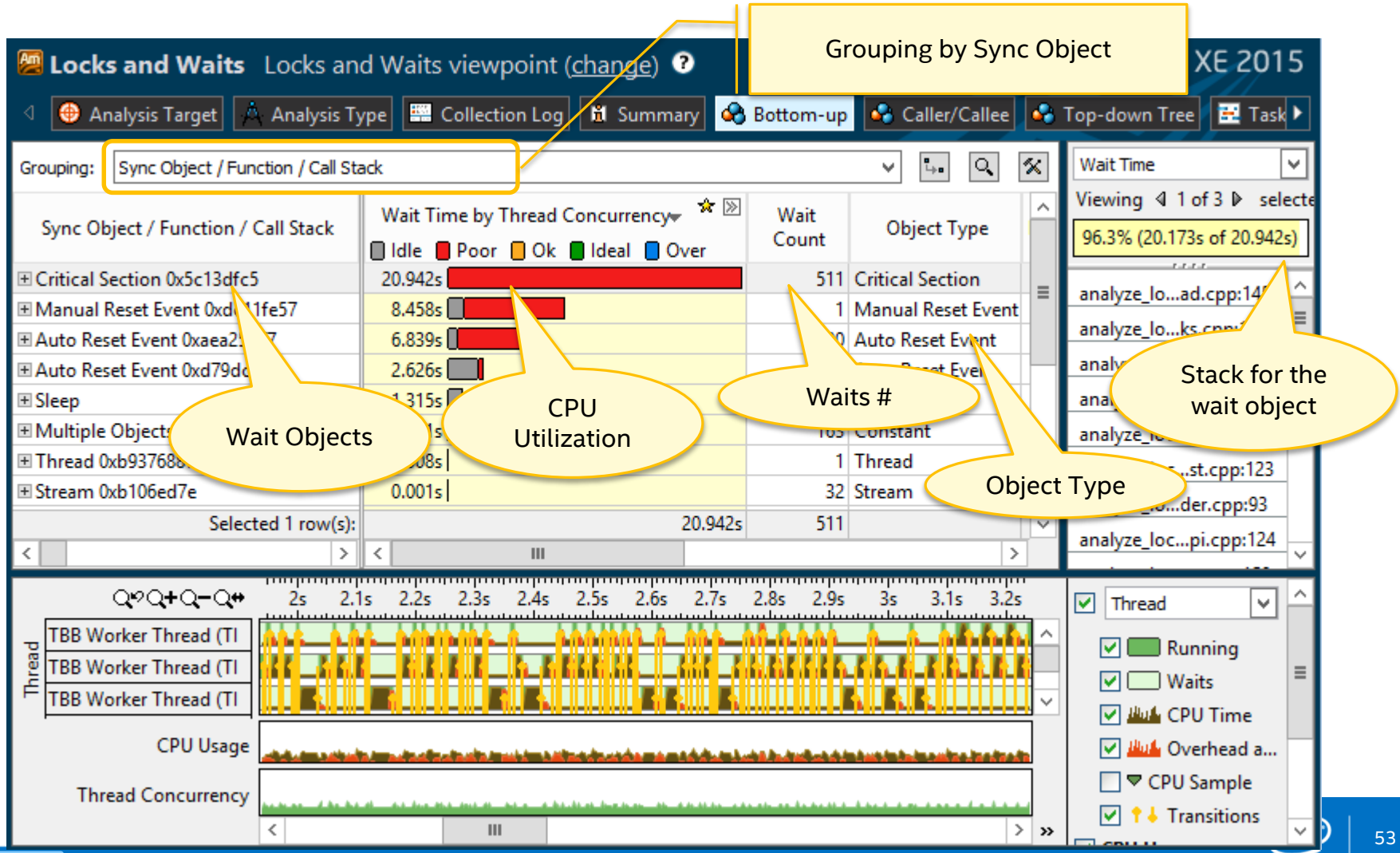
Identifies those threading items that are causing the most thread block time

- Synchronization locks
- Threading APIs
- I/O



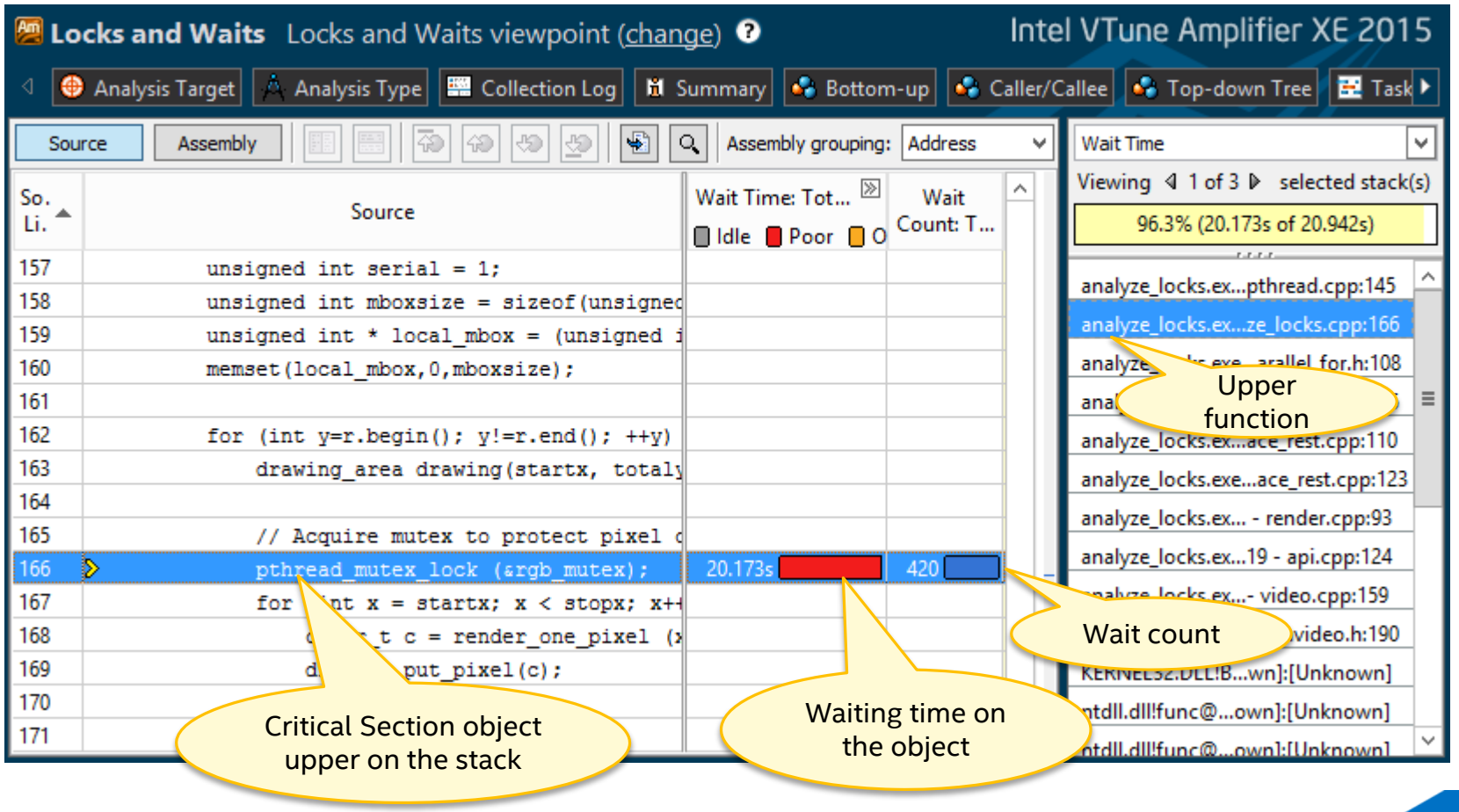
Locks and Waits Analysis

Sync/Wait objects



Locks and Waits Analysis

Source View



Intel® VTune™ Amplifier XE
User APIs

User APIs

- Collection Control API
- Thread Naming API
- User-Defined Synchronization API
- Task API
- User Event API
- Frame API
- JIT Profiling API

User API

Enable you to

- control collection
- set marks during the execution of the specific code
- specify custom synchronization primitives implemented without standard system APIs

To use the user APIs, do the following:

- Include ittnotify.h, located at <install_dir>/include
- Insert __itt_* notifications in your code
- Link to the libittnotify.lib file located at <install_dir>/lib

User API

Collection control and threads naming

Collection Control APIs

void __**itt_pause** (void)	Run the application without collecting data. VTune™ Amplifier XE reduces the overhead of collection, by collecting only critical information, such as thread and process creation.
void __**itt_resume** (void)	Resume data collection. VTune™ Amplifier XE resumes collecting all data.

Thread naming APIs

void __**itt_thread_set_name** (const __itt_char *name)	Set thread name using char or Unicode string, where *name* is the thread name.
void __**itt_thread_ignore** (void)	Indicate that this thread should be ignored from analysis. It will not affect the concurrency of the application. It will not be visible in the Timeline pane.

User API

Collection Control Example

```
int main(int argc, char* argv[])
{
    doSomeInitializationWork();

    __itt_resume();
    while(gRunning) {
        doSomeDataParallelWork();
    }
    __itt_pause();

    doSomeFinalizationWork();
    return 0;
}
```

Command Line Interface

Command line (CLI) versions exist on Linux* and Windows*

- **CLI use cases:**
  - Test code changes for performance regressions
  - Automate execution of performance analyses
- **CLI features:**
  - Fine-grained control of all analysis types and options
  - Text-based analysis reports
  - Analysis results can be opened in the graphical user interface

Command Line Interface
Examples

Display a list of available analysis types and preset configuration levels

```
amplxe-cl -collect-list
```

Run Hot Spot analysis on target *myApp* and store result in default-named directory, such as *r000hs*

```
amplxe-cl -c hotspots -- myApp
```

Run the Cuncurrency analysis, store the result in directory *r001par*

```
amplxe-cl -c concurrency -result-dir r001par -- myApp
```

Command Line Interface

Reporting

```
$> amplxe-cl -report summary -r
/home/user1/examples/lab2/r003cc

Summary
-------

Average Concurrency:   9.762
Elapsed Time:          158.749
CPU Time:              561.030
Wait Time:             190.342
CPU Usage:             3.636
Executing actions 100 % done
```

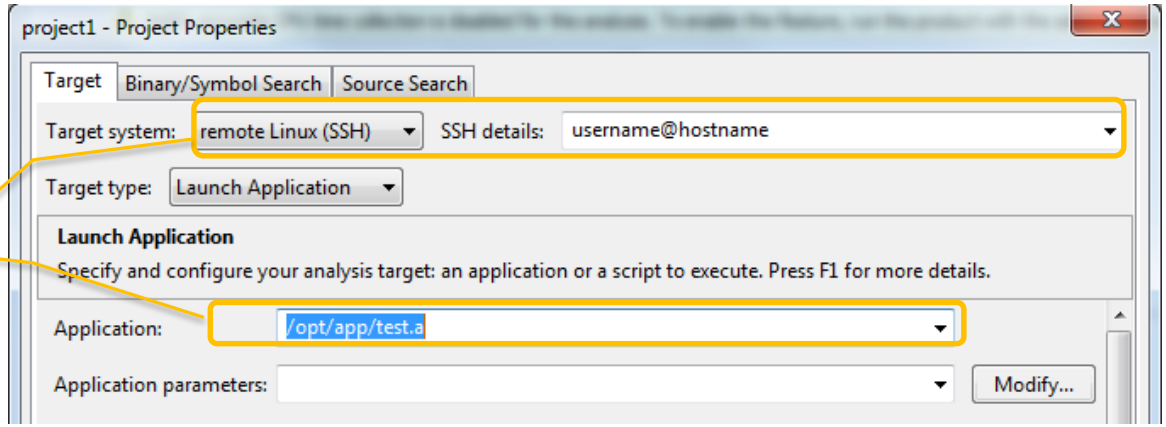
Command Line Interface

Gropof-like output

```
[levent@hlasnb AXE_lab3]$ amplxe-cl -report gprof-cc -r /home/levent/examples/cern/labs/AXE_lab3/r003cc
Using result path `/home/levent/examples/cern/labs/AXE_lab3/r003cc'
Executing actions 50 % Generating a report
Index  % Wait Time:Total  Wait Time:Self  Children  Name                                          Index
-----  -----------------  --------------  --------  --------------------------------------------  -----
                          190.104         190.104    G4RunManager::BeamOn                         [23]
[0]    99.88              190.104         0.0       ParRunManager::DoEventLoop                    [0]

                          0.162           0.162      operator<<                                   [17]
                          0.025           0.025      G4RunManagerKernel::G4RunManagerKernel       [11]
                          0               0.001      RunAction::EndOfRunAction                    [30]
[1]    0.1                0.186           0.001     G4strstreambuf::sync                          [1]
                          0.001           0.001      G4MycoutDestination::ReceiveG4cout           [5]

                          0.033           158.141    func@0x416c28                                [7]
[2]    83.08              0.033           158.108   main                                          [2]
                          0               158.108    G4_main                                      [18]

                          0.002           0.002      CLHEP::HepRandom::showEngineStatus           [22]
[3]    0.0                0.002           0.0       CLHEP::RanecuEngine::showStatus               [3]

                          0.001           0.001      G4_main                                      [18]
[4]    0.0                0.001           0.0       G4MycoutDestination::G4MycoutDestination      [4]

                          0.001           0.001      G4strstreambuf::sync                         [1]
[5]    0.0                0.001           0.0       G4MycoutDestination::ReceiveG4cout            [5]

                          0               0          G4UImanager::ExecuteMacroFile <cycle 1>      [28]
[6]    0.0                0.0             0.0       G4UIbatch::G4UIbatch                          [6]

[7]    83.08              0.0             158.141   func@0x416c28                                 [7]
                          0.033           158.141    main                                         [2]

                          0               190.107    G4_main                                      [18]
[8]    99.88              0.0             190.107   <cycle 1 as a whole>                          [8]
```

Remote Data Collection

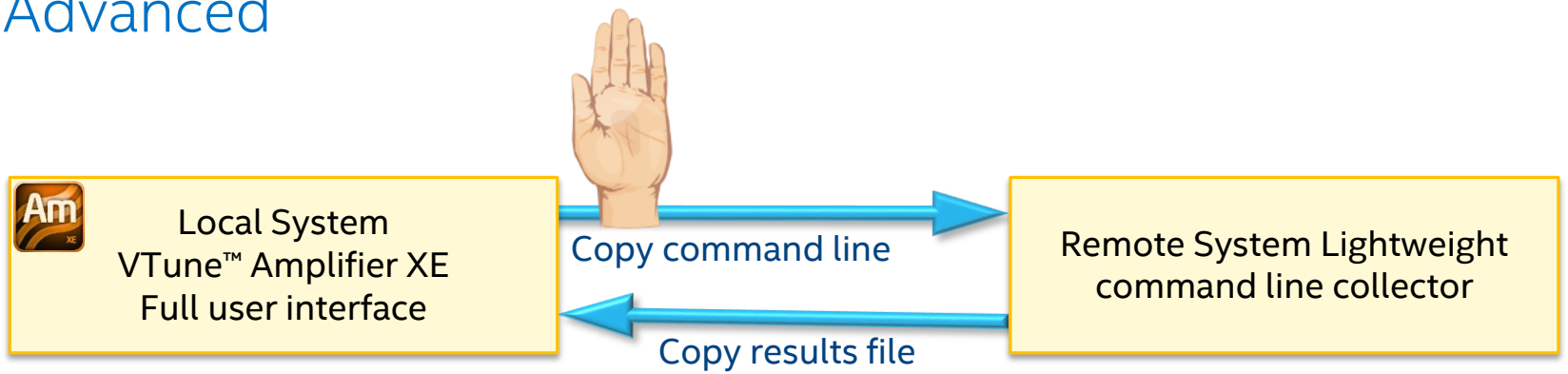
1. Setup the experiment using GUI locally
2. Configure remote target connection*
3. Specify application to run
4. Run analysis and get results copied to the Host automatically.



*Need to establish a passwordless ssh-connection

Remote Data Collection

Advanced



1. Setup the experiment using GUI locally
2. Copy command line instructions to paste buffer
3. Open remote shell on the target system
4. Paste command line, run collection
5. Copy result to your system
6. Open file using local GUI

One typical model

- Collect on Linux, analyze and display on Windows
  - The Linux machine is target
- Collect data on Linux system using command line tool
  - Doesn't require a license
- Copy the resulting performance data files to a Windows* system
- Analyze and display results on the Windows* system
  - Requires a license

Summary

The Intel® VTune Amplifier XE can be used to find:

- Source code for performance bottlenecks
- Characterize the amount of parallelism in an application
- Determine which synchronization locks or APIs are limiting the parallelism in an application
- Understand problems limiting CPU instruction level parallelism
- Instrument user code for better understanding of execution flow defined by threading runtimes

Questions?

Legal Disclaimer & Optimization Notice

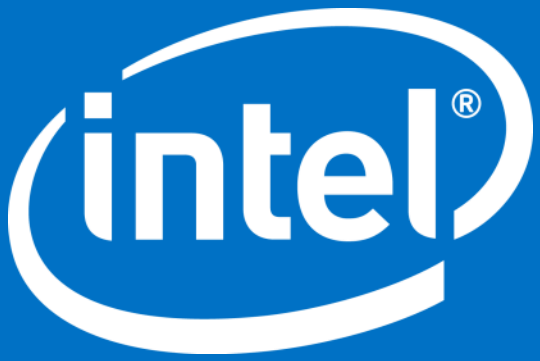
INFORMATION IN THIS DOCUMENT IS PROVIDED “AS IS”. NO LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT. INTEL ASSUMES NO LIABILITY WHATSOEVER AND INTEL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY, RELATING TO THIS INFORMATION INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products.

Optimization Notice

Intel’s compilers may or may not optimize to the same degree for non-Intel microprocessors for optimizations that are not unique to Intel microprocessors. These optimizations include SSE2, SSE3, and SSSE3 instruction sets and other optimizations. Intel does not guarantee the availability, functionality, or effectiveness of any optimization on microprocessors not manufactured by Intel. Microprocessor-dependent optimizations in this product are intended for use with Intel microprocessors. Certain optimizations not specific to Intel microarchitecture are reserved for Intel microprocessors. Please refer to the applicable product User and Reference Guides for more information regarding the specific instruction sets covered by this notice.

Notice revision #20110804


intel®