ROOT and x32-ABI

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On behalf of LHCb collaboration

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Outline

History of application binary interfaces

x86:

- 32-bit word size $\rightarrow$ 4GB addressable

x86_64 as an extension of x86:

- runs 32-bit as well as 64-bit applications
- 64-bit mode supports new hardware features
  - Number of CPU registers
  - Floating-point performance
  - Function parameters passed via registers
  - Syscall instruction ...

Why is a new binary interface necessary?

x86-64 (64-bit mode):

- new hardware features
- no memory limit
- slowdown due to memory issues
  - contention
  - page faults
  - paging ...

x86:

- very low memory footprint
- performance issues

x32-ABI - A new 32-bit ABI for x86-64

- Application Binary Interface based on 64-bit x86 architecture
- Reduces size of pointers and C-datatype long to 32-bit
- Takes advantage of all x64-features
- Avoids memory overhead

advantages of 64-bit instruction set
+
memory footprint of a 32-bit application

x32-ABI - A new 32-bit ABI for x86-64

- Developed by H.J. Lu (Intel)
- Introduced in Linux-Kernel 3.4 (released in summer 2012)
- `http://www.linuxplumbersconf.org/2011/ocw/sessions/531`
- Opinions in Linux-community differ quite a lot
  - 32-bit time values will overflow
  - adressable memory
  - ...

x32-ABI - A new 32-bit ABI for x86-64

Impressive results from x32-developers:

181.mcf from SPEC CPU 2000 (memory bound):

Intel Core i7

- *$\sim$ 40% faster than x86-64*
- *$\sim$ 2% slower than ia32*

Intel Atom

- *$\sim$ 40% faster than x86-64*
- *$\sim$ 1% faster than ia32*

x32-ABI - A new 32-bit ABI for x86-64

186.crafty from SPEC CPU 2000 (64bit integer):

Intel Core i7

$\sim$ *3 % faster than x86-64*

$\sim$ *40% faster than ia32*

Intel Atom

$\sim$ *4 % faster than x86-64*

$\sim$ *26% faster than ia32*

$\Longrightarrow$ CERN applications will definitely reduce memory footprint and very likely CPU-time

Preconditions

x32-ABI requires:

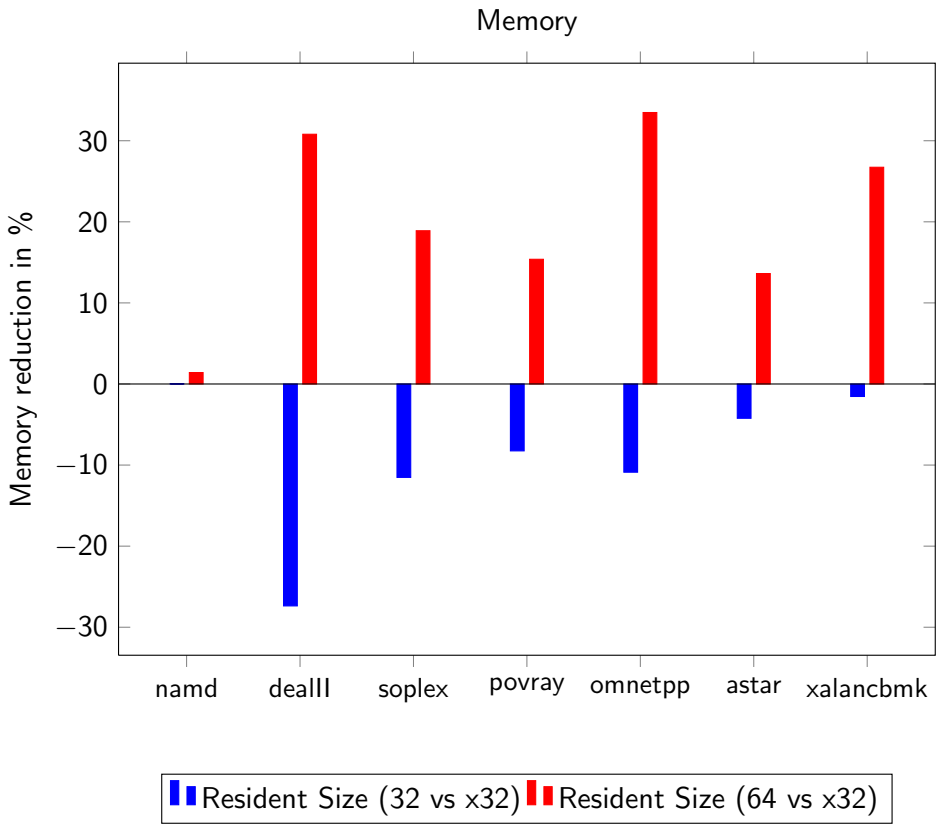
- Linux Kernel 3.4 compiled with CONFIG_X86_X32=y
- Gcc 4.7
- Binutils 2.22
- Glibc 2.16
- Recompiling all system libraries, required by an application, with gcc -mx32

```
ELF 32-bit LSB shared object, x86-64, version 1 (SYSV)
```

How ROOT can profit

- CERN applications use millions of pointers
  - GAUDI framework stores all events as pointers
  - Many virtual functions (virtual tables: function pointers and hidden pointers)
  - ROOT (histogram as a tree of pointers ...)
  - ...

Results within other CERN applications



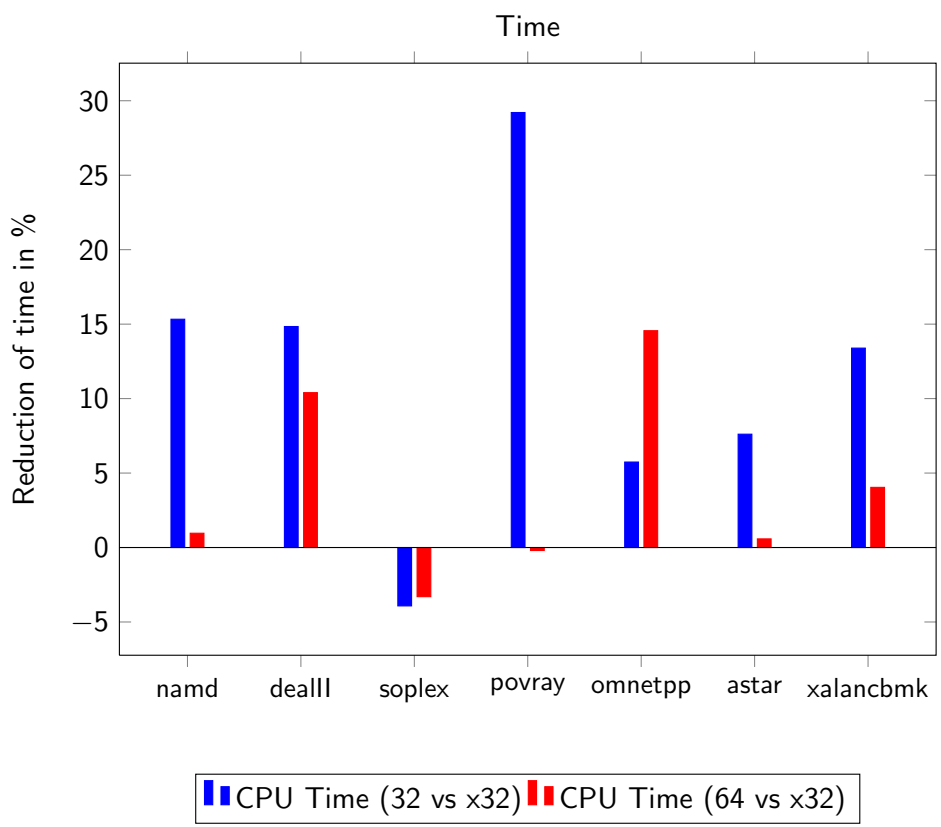


Figure : Comparison of memory consumption and CPU-time within the HEPSPEC-benchmarks

Results within other CERN applications

LHCb Reconstruction with Gaudiv23r3 and ROOT 5.34.00

Reconstruction of 1000 Events:

- Physical Memory: -20 %
- Total elapsed: -2 % reduction

LHCb Analysis with Gaudiv23r3 and ROOT 5.34.00

Analysis of 10000 Events:

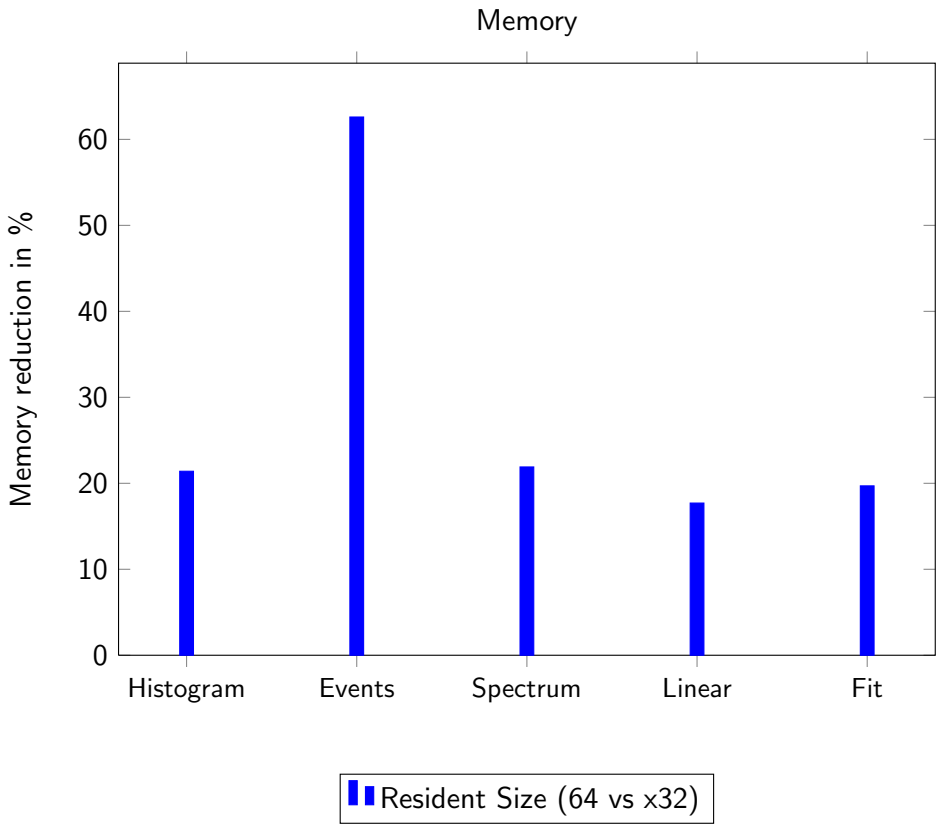
- Physical Memory: -21 %
- Total elapsed: 1.5 % increase

Results within ROOT-Benchmarks

Following ROOT-benchmarks:

- stressHistogram
- stress 1000
- stressHepix
  - IO
  - linear algebra
  - vector
  - sparse matrix

Results within ROOT-Benchmarks



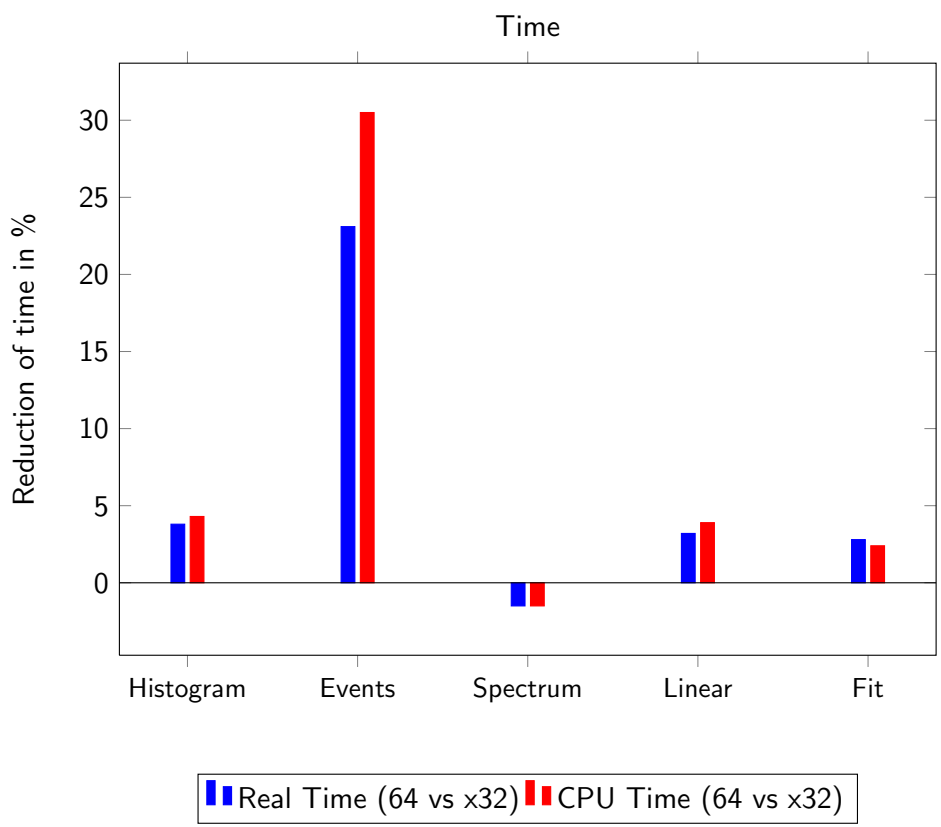
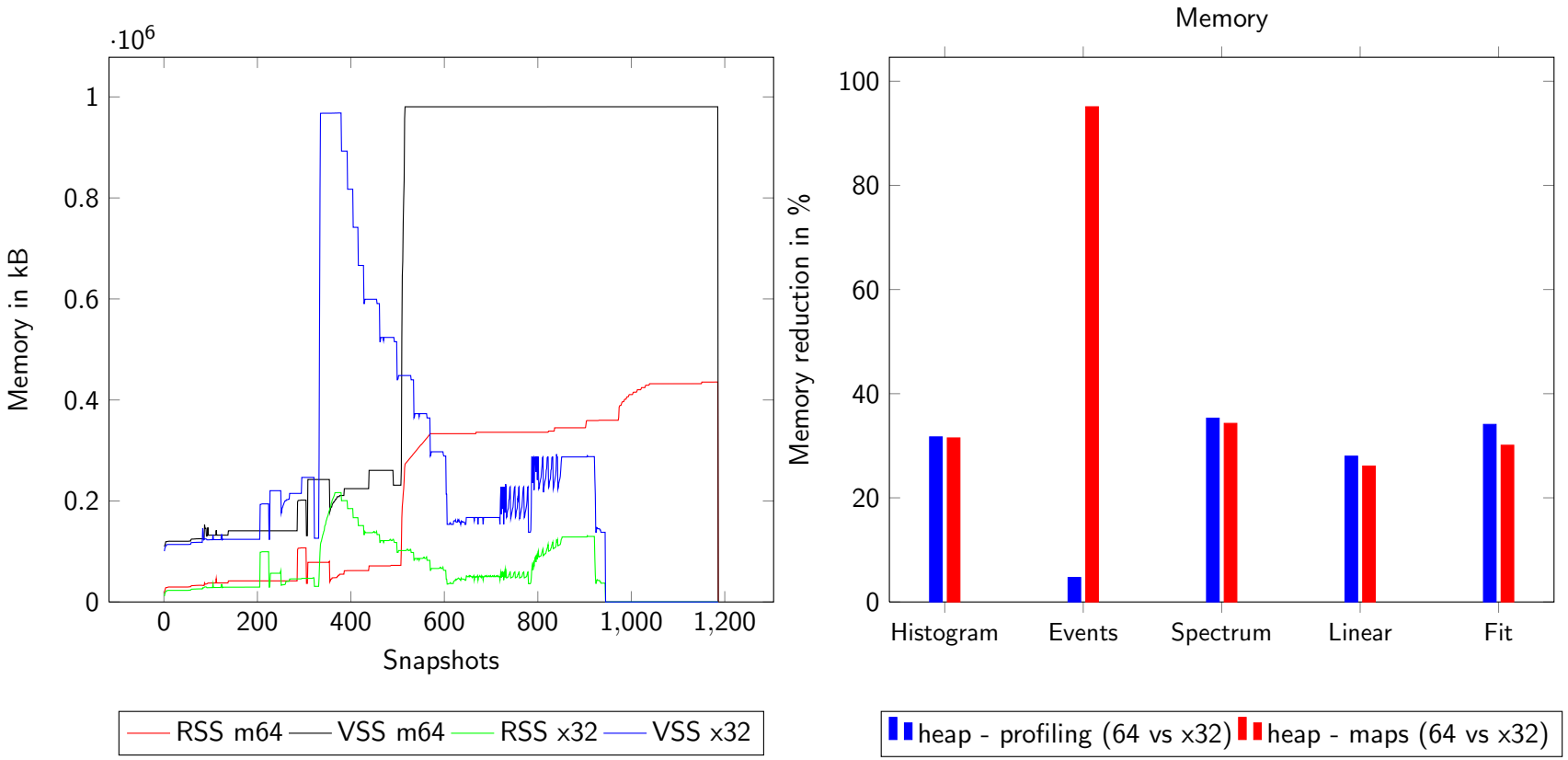


Figure : Comparison of memory consumption and CPU-time within the ROOT-benchmarks

Results within ROOT-Benchmarks

stress 1000:



Reasons for performance differences

- Memory seen by system and by process are different
- Default thresholds of *malloc*:
  - $t = 4 \cdot 1024 \cdot 1024 \cdot sizeof(long)$
  - if $x > t$: *malloc* uses *mmap*
  - if $x < t$: *malloc* uses *sbrk*
- *mmap*:
  - memory blocks can be independently given back
  - anonymous memory blocks as an extension of the heap
- *sbrk*:
  - memory blocks cannot be returned to the operating system

Reasons for performance differences

Looking into *dealII*, *omnetpp*, ROOT *stress*:

- *dealII*: page faults reduced by 10%
- *omnetpp*: page faults reduced by 38%
- *stress*: difference in CPU-time likely caused by memory issues

Further Issues:

- code and data alignment
- x32 loop unrolling needs some tuning
- zero-extensions for pointer conversion

$\Longrightarrow$ x32-ABI still under development and there are possiblities for optimization

Outline

Support of x32-ABI

- Ubuntu: Ongoing work, support planned for 13.04: `https://blueprints.launchpad.net/ubuntu/+spec/foundations-r-x32-planning`
- Gentoo: Release candidate available since summer 2012: `http://www.gentoo.org/news/20120608-x32_abi.xml`
- Red Hat: No plans according to: `http://comments.gmane.org/gmane.linux.redhat.fedora.devel/164019`
- LLVM-compiler: supports x32-ABI since summer 2012 `http://www.phoronix.com/scan.php?page=news_item&px=MTI3NTk`

Outline

Conclusion

- New room for improvement, (CERN) applications can profit substantially
- Computing Grid limits memory anyway to 4 GB per process
- Gain in performance is for **FREE**

Conclusion

Recompilation:

- Cast from time values to long (...) will produce wrong results (xrootd)
- New pointer size required modifications in CINT (function and data pattern)

Getting a working environment:

- does not work out of the box
- building gcc fails due to missing glibc x32
- building glibc x32 with a partly built gcc

Any questions?