MarlinMT - parallelising the Marlin framework.

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HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

AIDA 2020

ilc

DESY.

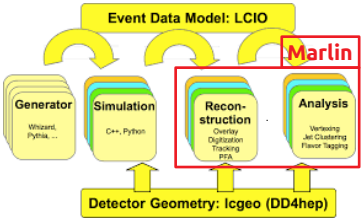
iLCSoft in a nutshell

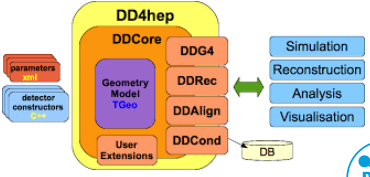
https://github.com/iLCSoft

- Software stack the ILC experiment
- Nowadays used by many other experiments/collaborations
  → e.g: CLICdp, CEPC, CALICE, LCTPC, EU-Telescope
- Maintained by FLC @ DESY and CLICdp @ CERN

Main components

- **DD4hep**: Geometry description for simulation (Geant4) and reconstruction
- **LCIO**: Linear Collider IO and EDM (2003)
- **Marlin**: Reconstruction framework based on LCIO





The Marlin framework

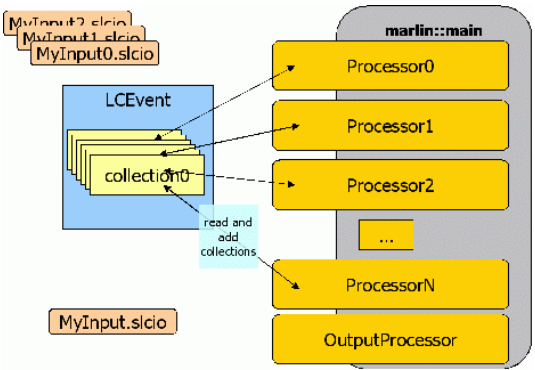
https://github.com/iLCSoft/Marlin

Standard HEP event processing framework

- **LCIO** as event data model
- **LCCD** for data condition handling
- **AIDA** for histogram handling

Main components

- `Processor`: Main user module
- Application steered via XML files
- Plugin mechanism
- Standard event processing pipeline.
  → **All sequential**
  → **Parallelization at process level**



The MarlinMT framework

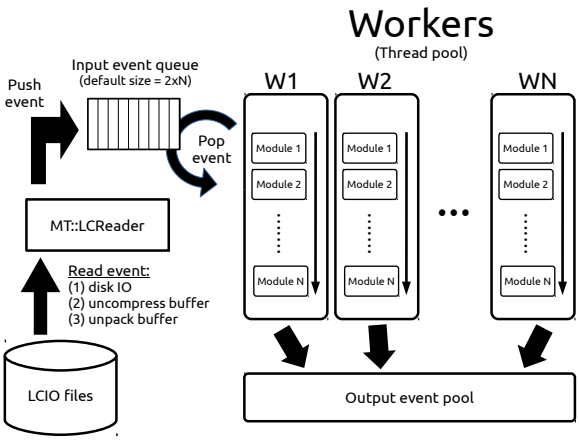
https://github.com/iLCSoft/MarlinMT

Choice of parallelism ?

- **Event parallelism only**, one thread per event
- No task parallelism
  - Introduces thread-safety additional requirements at user/framework level
  - Not mandatory for a first prototype
- Use only STL library for multi-threaded scheduler
  - Keep implementation simple
  - Keep dependencies minimal
  - May use TBB later...
- Processing pipeline replicated for each thread
  - Modules are cloned or shared
  - Depends on memory / thread-safety requirements

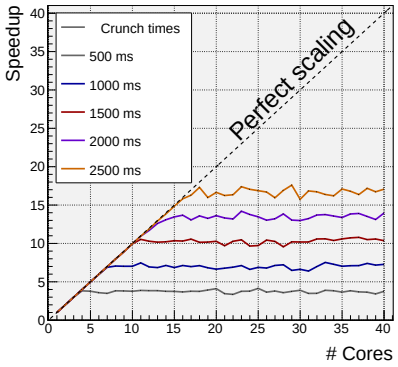
The PEP scheduler

Scheduler architecture



The PEP scheduler

First scaling performances



AMD EPYC 7451 24-Core (2 x 24 x 2 threads)

CPU crunching: crunch numbers for n *ms*

Amdahl's law:

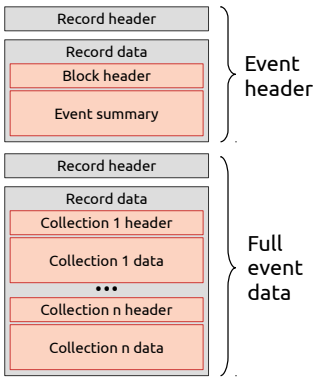
$$S_{latency} = \frac{1}{1 - p + \frac{p}{s}}$$

- Parallel code is CPU crunching
  $\rightarrow$ Limited by sequential code fraction
- Main sequential code:
  $\rightarrow$ LCIO file reading !
- **Need to reduce sequential code**

The SIO library

https://github.com/iLCSoft/SIO

- SIO is the IO layer of LCIO
- Re-implemented with thread-safety in mind
- Features:
  - Schema evolution (block versioning)
  - Pointer chasing (e.g linked-list)
  - Fast random access of records
  - Endianess agnostic (always write in big endian)
- LCIO event written in two records:
  - *Event header*: event summary (simple metadata)
  - *Event record*: all event collections

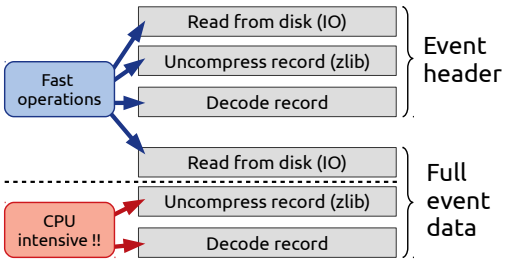


LCIO event structure

LCIO lazy unpacking with new SIO

LCIO lazy unpacking

1. Extract event record in a buffer
2. Move the buffer in `LCEvent`
3. Trigger full event decoding on first collection access

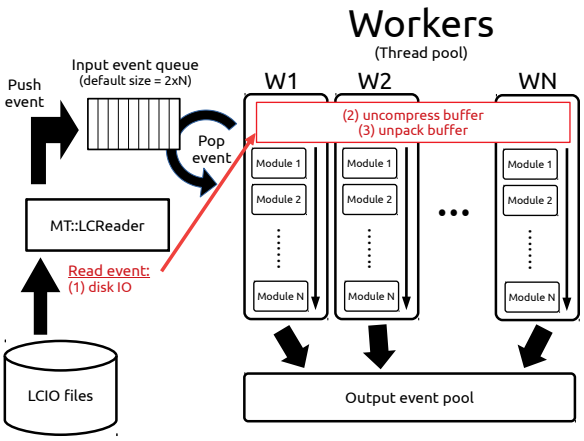


LCIO event decoding

Trigger CPU intensive decoding only on demand!

MarlinMT scheduler

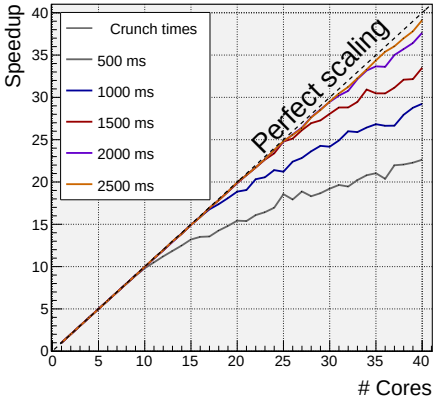
Parallel event processing - With lazy unpacking



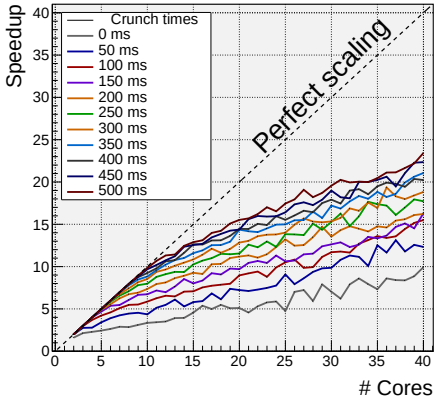
MarlinMT scheduler

Scaling performances with lazy unpacking

With LCIO lazy unpacking



With LCIO lazy unpacking



AMD EPYC 7451 24-Core (2 x 24 x 2 threads)

Histogramming and multi-threading

Common dilemma of histograms in multi-threaded frameworks:

- One histogram in N threads ? Nice for memory ! Killing CPU !
- N histogram copies in N threads ? Nice for CPU ! Killing memory !

What to choose ?

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Why not both in a framework?
Let the user choose where to win (and to lose)!

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Currently designing a book store `MarlinBook`

- ROOT7 histograms `ROOT::Experimental::RHist`
- Both histogram copy/shared at runtime
- Shared histograms: use thread local buffering
- ROOT6 or ROOT7 files
- Evaluating new RNTuple instead of TTree

Conclusion and outlook

Conclusion

- A prototype of MarlinMT has been developed:
  - Schedule parallel event processing in worker threads
  - Benchmarking doesn't show big issues → keep this implementation for now
- New SIO implementation
  - Full control on read/write steps: disk I/O, un/compression, en/de-coding
  - Allow for lazy data en/de-coding → Speeds up MarlinMT !
  - New SIO implementation used in other projects: see talk by `F. Gaede on PODIO`

Outlook

- Implement the book store `MarlinBook` (started)
- Porting exisiting reconstruction code will be a long journey

Backups

LCIO reading performance

Comparison of extract and decode times

		Extract time	Decode time	Read fraction	Event size
SIM	Single photon	2.583	33.116	12.821	1.34
	uds 200 GeV	9.399	79.45	8.453	3.05
	4f WW had	20	171	8.55	5.85
REC	Single photon	1.916	26.25	13.7	2.5
	uds 200 GeV	9.749	156.5	16.053	1
	4f WW had	20.1	331.7	16.502	55.6
DST	Single photon	0.085	0.088	1.035	0.0016
	uds 200 GeV	0.179	1.51203	8.447	0.052
	4f WW had	0.334	3.118	9.335	0.1

Table: LCIO file read performances (single thread). Read times in *milli-seconds*. Event size in MG. Read fraction defined as decode / extract. Results may vary on different machines.

Benchmarking machine

- Architecture: x86_64
- Byte Order: Little Endian
- CPU(s): 96
- Thread(s) per core: 2
- Core(s) per socket: 24
- Socket(s): 2
- NUMA node(s): 8
- CPU family: 23
- Model name: AMD EPYC 7451 24-Core Processor
- CPU MHz: 1200.000
- CPU max MHz: 2300.0000
- CPU min MHz: 1200.0000
- L1d cache: 32K
- L1i cache: 64K
- L2 cache: 512K
- L3 cache: 8192K