A path to convergence of build systems?

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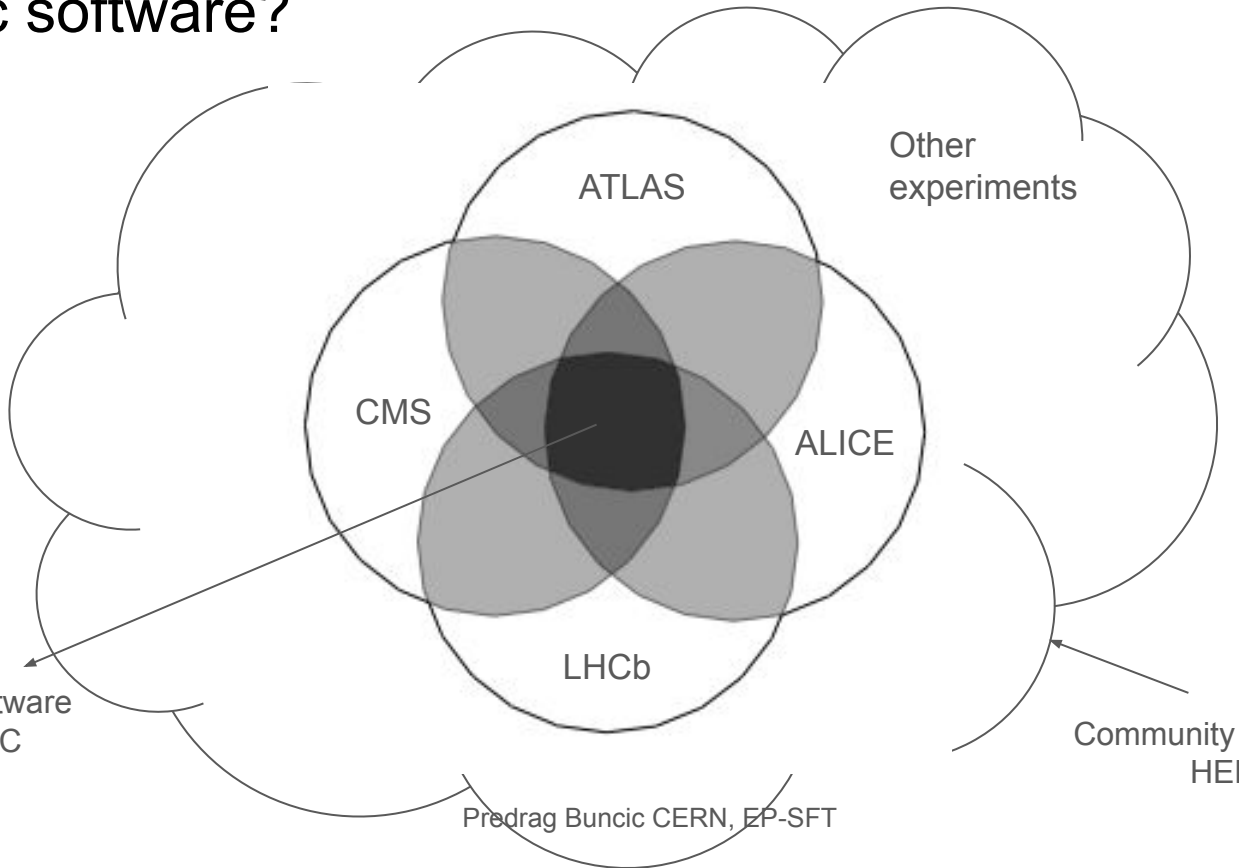
How do we collaborate and work towards the success of common scientific software?



Current practices

- SFT/SPI Builds and tests software stacks for LHC experiments
  - Uses in-house LCGCMake system to build and test the software stacks and distribute build products via CVMFS and RPMs as consistent releases
  - 800+ packages on many platform {CPU, OS, compiler, flags} combinations
- LHCb and ATLAS use the same (or similar) CMake-based approach to complement the builds done by SFT (externals) with their software components.
- To some extent, others benefit from CI and testing but build the software using their tools.
  - ALICE uses aliBuild to build their entire software stack
  - CMS uses cmsBuild to build its entire software stack

- Everyone uses CVMFS to publish software releases and nightly builds for testing
- Everyone is reasonably happy with their setup

Why change anything?

Previous attempts to converge in a common tool

- HSF Software Packaging Working Group Report (03/2016) ?
  - https://hepsoftwarefoundation.org/notes/HSF-TN-2016-03.pdf
- Discussion in the Architects Forum (10/2023)
  - Report from SPACK Working Group

	Linux	MacOS X	Windows	Xcompiler
aliBuild	+	+	-	+
cmsBuild	+	+	-	+
Contractor	+	+	-	+
Homebrew	o	+	-	-
LCGCMake	+	+	o	o
Nix	+	+	o	o
SciSoft	+	+	-	-
Spack	+	+	-	+
Worch	+	+	-	o

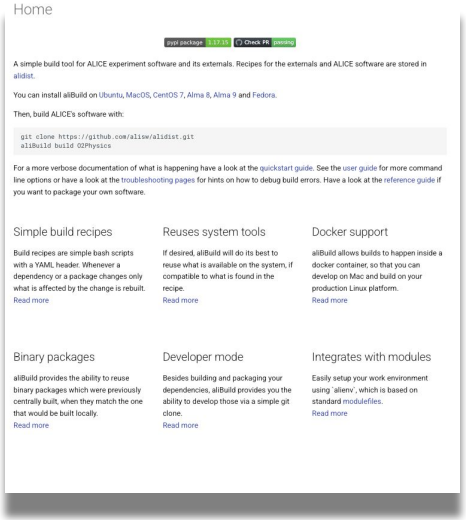
	Depends-On	Ease-Add-Pkg	Ease-Bootstrap	Documentation
aliBuild	Python	spec-file	+	o
cmsBuild	Python,rpm,apt	spec-file	o	-
Contractor	Python	python file	git checkout	-
Homebrew	Ruby	Formula	+	+
LCGCMake	Python, Cmake	Cmake-macro	+	o
Nix	Perl	expression	-	+
SciSoft	Cmake	Cmake-macro	o	-
Spack	Python	auto template	git checkout	+
Worch	Waf,Python	Text-files	+	o

	Multi-Rel	Multi-BuildVar	MultiShell-RTE	Relocation
aliBuild	+	+	+	+
cmsBuild	+	+	+	+
Contractor	+	+	NA	-
Homebrew	-	-	NA	-
LCGCMake	+	+	+	+
Nix	+	-	+	-
SciSoft	+	+	+	+
Spack	+	+	NA	-
Worch	+	+	+	+

	Performance	Sys-Reuse	Community	Unique-IDs	VCS-Support
aliBuild	+	o	-	+	+
cmsBuild	+	o	-	+	+
Contractor	+	+	-	-	+
Homebrew	+	+	+	-	+
LCGCMake	+	+	+	+	+
Nix	+	-	+	+	?
SciSoft	o	o	+	+	+
Spack	o	o	+	+	+
Worch	+	+	-	o	+

aliBuild (by Giulio Eulisse and ALICE)

- It was reviewed by the HSF in 2016, many improvements and production experience since then
- Shares DNA with CMS
  - Giulio Eulisse designed cmsBuild before joining ALICE and adapting the lessons learned in cmsBuild to the ALICE environment.
- Written in Python and bash
- Package description in the form of .sh script
  - Easy to translate build instructions
  - Metadata in the form of a YAML preamble
- Support for
  - Local development, caching and reuse of build products system tools and libraries
  - Automatic relocation, parallel software installations
- Produces tar files, RPMs (via separate helper script).
- Runtime package configuration based on environment modules
- Used in production since 2015.



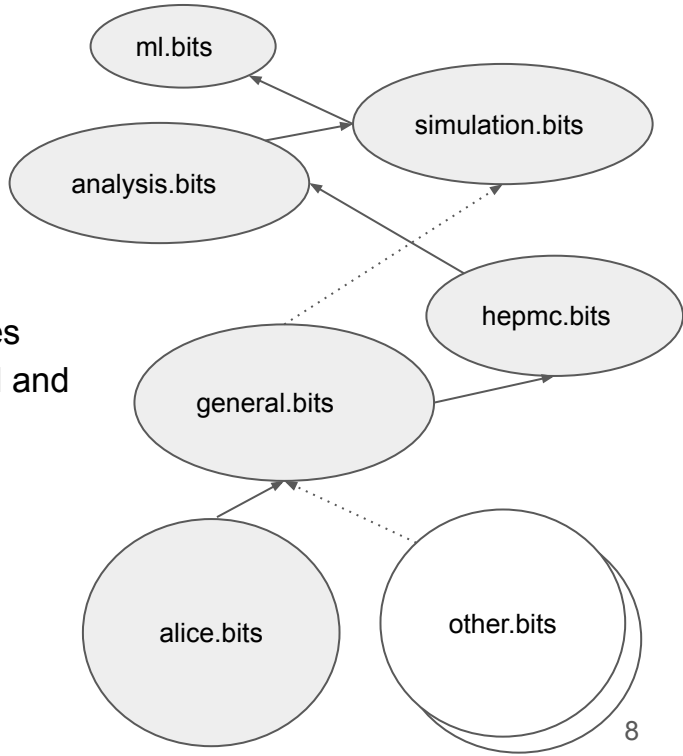
https://alisw.github.io/alibuild/

Lessons from the past

- AliEn BITS in 2003
  - It is possible to build and test ~200 (meta) packages with make driven tool (KDE Konstruct)
    - https://techbase.kde.org/Getting_Started/Build/Historic/Konstruct
- Grid Package Manager in 2004
  - It is better to use the file system than the package manager to distribute software (CVMFS)
- CernVM appliance in 2007
  - Built using Conary Package Manager by rPath
  - Had some great features
    - Could handle multiple repositories in search path
    - Reproducible builds in chroot environment
    - Relocating binary output to destination directory
    - Support for development and testing and release flows
    - Automated dependency discovery, parallel build (rMake, rBuilder)

BITS (demonstrator)

- BITS - A tool to Build, Integrate and Test Software packages
  - https://github.com/bitsorg on GitHub
  - Re-branded and extended aliBuild
    - Because names matter
    - As well as the backward compatibility
- Why start from aliBuild?
  - It covers most of the use cases
  - Simple and understandable recipes versioned in Git repositories
  - Written in Python and bash, it is relatively simple to understand and extend
- Extensions wrt aliBuild
  - Added support for multiple package repositories
  - Supports individually versioned package directories
  - Allows for parallel build flows on a single node and beyond
    - ~20% gain in build speed for ALICE case
  - Simplified build recipes



What about next 20 years?

- In an ideal world where all (LHC) experiments agree to use a common build tool
  - We work together to improve the common tool to meet all our requirements.
  - SFT builds general, hepmc, simulation, analysis and ml package groups and distributes them on CVMFS
  - The tool is specifically optimized to use CVMFS as an efficient distribution channel for software and reusable build products.
  - Experiments using the same tool add and maintain their repositories while benefiting from shared package build recipes.
  - Different CI pipelines run concurrently (possibly on the same shared build infrastructure), optimizing usage of personpower and computing resources.
  - Everyone is happy

Conclusions

- There are many package managers out there
  - Usually adapted to specific use cases
  - It is often easier to write a new one than to convince others to use the common one
- The software stacks of the LHC experiments differ
  - There are also significant overlaps
- The use cases must be almost identical
  - It should be possible to meet them in one tool
- Shouldn’t we, as the community (LHC experiments, at least), finally start acting rationally, save effort and resources, agree on a homegrown tool, and, if needed, adapt it to match all our needs?
  - If so, SFT is willing to help.
  - But we need at least two experiments to sign up.
- BITS demo is a work in progress
  - This is the right moment to express interest and join the development

To BITS, or not to BITS, that is the question [for discussion]

Backup

Summary of common software packages (in production)

- Common Software used and developed by the HEP Community:
  - **Geant4, ROOT**, fastjet, xrootd (4)
  - **VecGeom**, dd4hep, AIDA (2)
- MC Generators and tools:
  - hepmc, hepmc3, starlight, pythia6, lhapdf (4)
  - heppdt, rivet, thepeg, yoda, pythia8 (3)
  - evtgen, crmc, herwig3, hydjet, madgraph5amc, pyquen, sherpa, mctester (2)
- Scientific computing libraries (not strictly HEP):
  - boost, gsl (4)
  - blas, clhep, eigen, vdt (3)
  - onnxruntime, tensorflow, xgboost, matplotlib (2)
- Other commonly used libraries (not HEP specific)
  - tbb, fmt, freetype, jemalloc, libffi, libunwind, libxml2,sqlite, protobuf (4)

Input used for comparison

CMS

bseil-cpp alpaka alpgen autotools axol1tl bazel bison blackhat boost bz2lib c-ares catch2 celeritas cepgen cicada clang-uml classlib clhep cmake cms-git-tools cmslhetoeosmanager cmsmon-tools cmssw-osenv cmssw-wm-tools cmsswdata collier conifer coral cppunit cpu_features crab crab-dev crab-pre crab-prod csctrackfinderemulation cuda cuda-compatible-runtime cudnn curl dablooms das_client dasgoclient data-alignment-offlinevalidation data-calibcalorimetry-calomiscalibtools data-calibcalorimetry-ecaltrivialcondmodules data-calibpps-esproducers data-calibration-tools data-calibtracker-sipixelesproducers data-calibtracker-sistripdcs data-condformats-jetmetobjects data-condtools-hcal data-condtools-siphase2tracker data-condtools-sistrip data-configuration-generator data-dataformats-common data-dataformats-detid data-dataformats-fedrawdata data-dataformats-hltreco data-dataformats-l1scouting data-dataformats-l1scoutingrawdata data-dataformats-l1tglobal data-dataformats-patcandidates data-dataformats-scouting data-dataformats-sistripcluster data-detectordescription-schema data-dqm-dtmonitorclient data-dqm-ecalmonitorclient data-dqm-hcaltasks data-dqm-integration data-dqm-physicshww data-dqm-sistripmonitorclient data-egammaanalysis-electrontools data-eventfilter-l1trawtodigi data-fastsimulation-materialeffects data-fastsimulation-trackingrechitproducer data-fireworks-geometry data-fwcore-modules data-generatorinterface-evtgeninterface data-generatorinterface-reggegribovpartonmcinterface data-geometry-dtgeometrybuilder data-geometry-hgcalmapping data-geometry-testreference data-heterogeneouscore-sonictriton data-hltrigger-jetmet data-iopool-input data-l1trigger-csctriggerprimitives data-l1trigger-dttriggerphase2 data-l1trigger-l1calotrigger data-l1trigger-l1tcalorimeter data-l1trigger-l1tglobal data-l1trigger-l1thgcal data-l1trigger-l1tmuon data-l1trigger-l1tmuonendcapphase2 data-l1trigger-l1ttrackmatch data-l1trigger-phase2l1particleflow data-l1trigger-rpctrigger data-l1trigger-trackfindingtmtt data-l1trigger-trackfindingtracklet data-l1trigger-tracktrigger data-l1trigger-vertexfinder data-l1triggerconfig-l1tconfigproducers data-magneticfield-engine data-magneticfield-interpolation data-physicstools-nanoaod data-physicstools-patutils data-recobtag-combined data-recobtag-ctagging data-recobtag-secondaryvertex data-recobtag-softlepton data-recoctpps-totemrplocal data-recoecal-egammaclusterproducers data-recoegamma-egammaphotonproducers data-recoegamma-electronidentification data-recoegamma-photonidentification data-recohgcal-ticl data-recohi-hijetalgos data-recojets-jetproducers data-recolocalcalo-ecaldeadchannelrecoveryalgos data-recomet-metpusubtraction data-recomtd-timingidtools data-recomuon-muonidentification data-recomuon-trackerseedgenerator data-recoparticleflow-pfblockproducer data-recoparticleflow-pfproducer data-recoparticleflow-pftracking data-recopps-local data-recotautag-trainingfiles data-recotracker-displacedregionaltracking data-recotracker-finaltrackselectors data-recotracker-mkfit data-recotracker-tkseedgenerator data-simcalorimetry-ecalebtrigprimproducers data-simg4cms-calo data-simg4cms-forward data-simg4cms-hgcaltestbeam data-simpps-ppspixeldigiproducer data-simtracker-sistripdigitizer data-simtransport-hectorproducer data-simtransport-ppsprotontransport data-simtransport-totemrpprotontransportparametrization data-slhcupgradesimulations-geometry data-validation-geometry data-validation-hgcalvalidation davix db6 dcap dd4hep dip dqmgui dwz eigen evtgen expat fakesystem fasthadd fastjet fastjet-contrib fastjet_x86-64-v3 fftjet fftw3 flatbuffers flex fmt form freetype frontier_client fxdiv g4hepem gbl gbl_x86-64-v3 gcc gcc-fixincludes gdb gdbm gdrcopy geant4 geant4-g4abla geant4-g4emlow geant4-g4ensdfstate geant4-g4incl geant4-g4ndl geant4-g4particlexs geant4-g4photonevaporation geant4-g4radioactivedecay geant4-g4realsurface geant4-g4saiddata geant4data giflib git glimpse gmake gnuplot go google-benchmark gosam gosamcontrib gperftools grpc gsl hdf5 heaptrack hector hepmc hepmc3 heppdt herwig7 highfive hls hls4mlemulatorextras hwloc hydjet hydjet2 icc icx igprof intel-vtune ittnotify java-env jemalloc jemalloc-debug jemalloc-prof json ktjet l1metml lcov lhapdf libffi libjpeg-turbo libpciaccess libpng libtiff libungif libunwind libuuid libxml2 libxslt libzmq llvm log4cplus lwtnn lwtnn_x86-64-v3 lz4 madgraph5amcatnlo mcfm mctester md5 meschach millepede mozsearch nasm ninja numactl onnxruntime openblas openblas_x86-64-v3 opencl opencl-cpp opencv opencv_x86-64-v3 openldap openloops openloops-process openmpi oracle pacparser pcre pcre2 photospp professor2 protobuf psimd py3-absl-py py3-aiohttp py3-aiosignal py3-aiosqlite py3-annotated-types py3-anyio py3-appdirs py3-argon2-cffi py3-argon2-cffi-bindings py3-argparse py3-arrow py3-asn1crypto py3-astor py3-astroid py3-asttokens py3-astunparse py3-async-lru py3-async-timeout py3-atomicwrites py3-attrs py3-autopep8 py3-avro py3-awkward py3-awkward-cpp py3-awkward-pandas py3-babel py3-backcall py3-backports-entry-points-selectable py3-backports-tarfile py3-beautifulsoup4 py3-beniget py3-bleach py3-blosc2 py3-boost-histogram py3-bottleneck py3-build py3-cachecontrol py3-cachetools py3-cachy py3-calver py3-certifi py3-cffi py3-chardet py3-charset-normalizer py3-cleo py3-click py3-clikit py3-cloudpickle py3-cms-tfaot py3-cmsml py3-colorama py3-comm py3-commonmark py3-contextlib2 py3-contextvars py3-contourpy py3-correctionlib py3-coverage py3-cppy py3-cramjam py3-crashtest py3-cryptography py3-cx-oracle py3-cycler py3-cython py3-dask py3-dask-awkward py3-debugpy py3-decorator py3-defusedxml py3-deprecated py3-deprecation py3-dill py3-distlib py3-distro py3-docopt py3-docutils py3-dulwich py3-dxr py3-editables py3-entrypoints py3-exceptiongroup py3-execnet py3-executing py3-expandvars py3-fastjsonschema py3-filelock py3-fire py3-flake8 py3-flatbuffers py3-flawfinder py3-flit py3-flit-core py3-flit-scm py3-fonttools py3-frozenlist py3-fsspec py3-funcsigs py3-future py3-gast py3-gitdb py3-gitpython py3-google-auth py3-google-auth-oauthlib py3-google-pasta py3-grpcio py3-grpcio-tools py3-h11 py3-h5py py3-hatch-fancy-pypi-readme py3-hatch-jupyter-builder py3-hatch-nodejs-version py3-hatch-vcs py3-hatchling py3-hepdata-lib py3-hepdata-validator py3-hist py3-histbook py3-histogrammar py3-histoprint py3-html5lib py3-httpcore py3-httpx py3-idna py3-immutables py3-importlib-metadata py3-importlib-resources py3-iniconfig py3-installer py3-ipaddress py3-ipykernel py3-ipython py3-ipython_genutils py3-ipywidgets py3-isort py3-jaraco-classes py3-jaraco-context py3-jaraco-functools py3-jax py3-jedi py3-jeepney py3-jinja2 py3-jinja2-time py3-joblib py3-json5 py3-jsonpickle py3-jsonschema py3-jsonschema-specifications py3-jupyter-client py3-jupyter-console py3-jupyter-core py3-jupyter-events py3-jupyter-lsp py3-jupyter-packaging py3-jupyter-server py3-jupyter-server-terminals py3-jupyterlab py3-jupyterlab-pygments py3-jupyterlab-server py3-jupyterlab-widgets py3-keras py3-keras-applications py3-keras-preprocessing py3-keras2onnx py3-keyring py3-kiwisolver py3-law py3-lazy-object-proxy py3-lizard py3-locket py3-lockfile py3-luigi py3-lxml py3-lz4 py3-make py3-mako py3-markdown py3-markdown-it-py py3-markupsafe py3-matplotlib py3-matplotlib-inline py3-maturin py3-mccabe py3-mdurl py3-meson py3-meson-python py3-mistune py3-ml_dtypes py3-mock py3-more-itertools py3-mplhep py3-mplhep-data py3-mpmath py3-msgpack py3-multidict py3-nbclient py3-nbconvert py3-nbformat py3-ndindex py3-nest-asyncio py3-networkx py3-notebook py3-notebook-shim py3-numexpr py3-numpy py3-nvidia-ml-py py3-oauthlib py3-onnx py3-onnxconverter-common py3-onnxmltools py3-opt-einsum py3-packaging py3-pandas py3-pandocfilters py3-parsimonious py3-parso py3-partd py3-pastel py3-pathlib2 py3-pathspec py3-pbr py3-pexpect py3-pickleshare py3-pillow py3-pip py3-pkgconfig py3-pkginfo py3-plac py3-platformdirs py3-pluggy py3-ply py3-poetry py3-poetry-core py3-poetry-plugin-export py3-prettytable py3-prometheus-client py3-prompt_toolkit py3-protobuf py3-prwlock py3-psutil py3-ptyprocess py3-pure-eval py3-py-cpuinfo py3-pyasn1 py3-pyasn1-modules py3-pybind11 py3-pycodestyle py3-pycparser py3-pycuda py3-pycurl py3-pydantic py3-pydantic-core py3-pydot py3-pyflakes py3-pygithub py3-pygments py3-pyjwt py3-pylev py3-pylint py3-pynacl py3-pyparsing py3-pyproject-hooks py3-pyproject-metadata py3-pysocks py3-pysqlite3 py3-pytest py3-pytest-cov py3-pytest-runner py3-pytest-xdist py3-python-daemon py3-python-dateutil py3-python-json-logger py3-python-ldap py3-python-rapidjson py3-pythran py3-pytoml py3-pytools py3-pytz py3-pyyaml py3-pyzmq py3-rapidfuzz py3-referencing py3-regex py3-repoze-lru py3-requests py3-requests-oauthlib py3-requests-toolbelt py3-rfc3339-validator py3-rfc3986-validator py3-rich py3-rpds-py py3-rsa py3-scandir py3-schema py3-scikit-build py3-scikit-build-core py3-scikit-learn py3-scinum py3-scipy py3-seaborn py3-secretstorage py3-semantic-version py3-send2trash py3-setuptools py3-setuptools-rust py3-setuptools-scm py3-shellingham py3-simplegeneric py3-singledispatch py3-six py3-skl2onnx py3-smmap py3-sniffio py3-soupsieve py3-sqlalchemy py3-stack-data py3-stevedore py3-subprocess32 py3-sympy py3-tables py3-tabulate py3-tenacity py3-tensorboard py3-tensorboard-data-server py3-tensorboard-plugin-wit py3-tensorflow py3-tensorflow-estimator py3-tensorflow-io-gcs-filesystem py3-termcolor py3-terminado py3-testpath py3-threadpoolctl py3-tinycss2 py3-toml py3-tomli py3-tomli-w py3-tomlkit py3-toolz py3-tornado py3-tqdm py3-traitlets py3-trove-classifiers py3-typed-ast py3-types-python-dateutil py3-typing-extensions py3-tzdata py3-uhi py3-uncertainties py3-uproot py3-urllib3 py3-vector py3-versioneer py3-virtualenv py3-virtualenv-clone py3-virtualenvwrapper py3-wcwidth py3-webencodings py3-websocket-client py3-werkzeug py3-wheel py3-widgetsnbextension py3-wrapt py3-xgboost py3-yarl py3-zipp pyquen pythia6 pythia8 python-python3 python3 pytorch pytorch-cluster pytorch-custom-ops pytorch-scatter pytorch-sparse pytorch_x86-64-v3 qd qgraf rapidjson rdma-core re2 re2c rivet rivet_x86-64-v3 rocm rocm-rocrand root rust scramv1 scramv2 sherpa sigcpp sloccount sqlite starlight swig tauolapp tbb tensorflow tensorflow-sources tensorflow-sources_x86-64-v3 tensorflow-xla-runtime tensorflow_x86-64-v3 tfaot-model-test-multi tfaot-model-test-simple thepeg tinyxml2 tkonlinesw toollip triton-inference-client ucx utm valgrind vdt vecgeom xerces-c xgboost xpmem xrdcl-record xrootd xtensor xtl xz yaml-cpp yoda zlib zlib_x86-64-v3

Input used for comparison

LHCB

aida boost cmake catch2 cppunit dd4hep davix edm4hep form gsl generator gitconddb graphics hepmc heppdt io jinja2 lcio machine markupsafe math other pyyaml python relax root sio simulation tool vc xml xercesc absl_py appdirs argon2_cffi asn1crypto assimp astor astunparse async_generator atomicwrites attrs babel backcall beautifulsoup4 beniget bison blas bleach bokeh build cachetools cairo capturer catboost certifi cffi cfitsio chardet charset_normalizer clhep click cmaketools collier coloredlogs contourpy coverage cppgsl crmc cryptography cycler cython debugpy decorator defusedxml dill distlib docutils doxygen eigen entrypoints et_xmlfile exceptiongroup fastjet fastjsonschema feynhiggs fftw filelock fjcontrib flatbuffers flex fmt fontconfig fonttools freetype fribidi fs fsspec funcsigs future gast gdb geos gettext gl2ps glib go go_demangle go_liner go_readline go_runewidth google_auth google_auth_oauthlib google_pasta gosam gosam_contrib gperf gperftools graphviz grpcio h5py harfbuzz hdf5 hepmc3 herwig3 html5lib humanfriendly hypothesis idna importlib_metadata importlib_resources iniconfig ipykernel ipyparallel ipython ipython_genutils jax jaxlib jedi jemalloc joblib jsonmcpp jsonschema jsonschema_specifications jupyter_client jupyter_core jupyterlab_pygments keras keras_applications keras_preprocessing kiwisolver lcgenv lhapdf libclang libffi libgit2 libsodium libtool libunwind libxml2 libxslt linkify_it_py looptools lxml madgraph5amc markdown markdown_it_py matplotlib matplotlib_inline mdit_py_plugins mdurl meson messaging mistune ml_dtypes mock more_itertools mpfr mpmath msgpackc multiprocess mypy mypy_extensions mysql nbclient nbconvert nbformat nest_asyncio networkx ninja njet nodejs nose notebook numpy oauthlib odfpy onnx onnxruntime openloops openpyxl opt_einsum oracle packaging pandas pandocfilters panel pango param parso pathlib2 pathos pbr pcre pcre2 pep517 pexpect photos++ pickleshare pillow pip pixman pkg_config platformdirs pluggy ply png podio powheg-box-v2 pox ppft pprof prometheus_client prompt_toolkit protobuf ptyprocess py pyasn1 pyasn1_modules pybind11 pycairo pycparser pyct pydantic pydot pydot_ng pygments pyparsing pyrsistent pytest pytest_cov pythia6 pythia8 python_dateutil pythran pytz pyviz_comms pyzmq qd qgraf railroad_diagrams rangev3 referencing requests requests_oauthlib rivet rpds_py rsa ruamel_yaml ruamel_yaml_clib scandir scikitlearn scipy send2trash setuptools setuptools_scm shapely simplegeneric six sortedcontainers soupsieve spdlog sqlite starlight swig sympy syscalc tauola++ tbb tensorboard tensorboard_data_server tensorboard_plugin_wit tensorflow tensorflow_estimator tensorflow_io_gcs_filesystem termcolor terminado testpath texinfo theano thepeg threadpoolctl tinycss2 toml tomli torch tornado tqdm traitlets typed_ast typing_extensions uc_micro_py umesimd urllib3 valgrind vbfnlo vcversioner vdt veccore vectorclass verboselogs virtualenv wcwidth webencodings werkzeug wheel wrapt xapian xgboost xlrd xqilla xrootd xyzservices yamlcpp yoda zeromq zipp

Input used for comparison

ATLAS

aida authlib boost cppunit davix form frontier_client gsl generator graphics hepmc heppdt io machine math other pyjwt pyyaml python qt5 relax root sfgen simulation tool vc xml xercesc absl apfel appdirs asn1crypto atomicwrites attrs auth_get_sso_cookie autopep8 backcall beautifulsoup4 beniget bison blas boto3 botocore build c_ares cairo ccache certifi cffi cfitsio chardet charset_normalizer clhep click cmaketools coin3d collier configobj contourpy contur coverage cppgsl cppy crmc cryptography cuda cudnn cx_oracle cycler cython decorator defusedxml dill distlib distro docopt doxygen eigen entrypoints et_xmlfile evtgen exceptiongroup fastjet feynhiggs fftw filelock fjcontrib flake8 flake8_bugbear flake8_builtins flex fmt fontconfig fonttools freetype fribidi fs funcsigs future gast gdb geneva gettext git gl2ps glib go go_demangle go_liner go_readline go_runewidth gosam gosam_contrib gperf gperftools graphviz greenlet grpc gssapi gtest harfbuzz hdf5 hdf5_mpi heaptrack hepmc3 hepmcanalysis heputils herwig3 highfive hijing hto4l hwloc hydjet hypothesis idna igprof importlib_metadata importlib_resources iniconfig ipython ipython_genutils java jedi jemalloc jmespath joblib jsonmcpp kiwisolver kokkos lcgenv lhapdf libffi libm_aocl libsodium libtool libunwind libxml2 libxslt looptools lxml madgraph5amc matplotlib maven mccabe mcfm mctester mcutils meson messaging mock more_itertools mpfr mpmath msgpackc multiprocess mypy mypy_extensions mysql ninja njet nose numpy odfpy openloops openmpi openpyxl oracle oracledb packaging pacparser pandas pango parso pathos pbr pcre pcre2 pep517 pepper_kokkos pexpect photos++ pickleshare pillow pip pixman pkg_config platformdirs pluggy ply png pox ppft pprof prompt_toolkit prophecy4f protobuf protobuf2 psutil ptyprocess py pybind11 pycairo pycodestyle pycparser pyflakes pygments pygraphviz pyparsing pypng pyqt5 pyqt5_sip pyqt_builder pyquen pyslha pytest pytest_runner pythia6 pythia8 python_dateutil pythran pytz qd qgraf qrcode railroad_diagrams rangev3 re2 requests requests_gssapi rivet s3transfer scikitlearn scipy setuptools setuptools_scm sherpa sherpa-openmpi simplegeneric sip six sortedcontainers soupsieve sqlalchemy sqlite starlight stomppy superchic swig sympy syscalc tauola++ tbb texinfo thep8i thepeg threadpoolctl tiff toml tomli tornado tqdm traitlets typing_extensions tzdata urllib3 valgrind vbfnlo vdt virtualenv wcwidth wheel xapian xlrd xrootd yoda zeromq zipp

Input used for comparison

ALICE

bseil aegis alice-grid-utils alien-cas alien-runtime aliphysics aliroot apmon-cpp arrow base bookkeeping-api boost bz2 c-ares capstone cgal clang cmake common-o2 configuration control-occplugin curl datadistribution dds debuggui double-conversion dpmjet evtgen faircmakemodules fairlogger fairmq fairroot fastjet fftw3 flatbuffers fmt freetype gcc-toolchain geant3 geant4 geant4_vmc generators glfw gmp googlebenchmark grid-base-packages grpc gsl hepmc hepmc3 igprof itsresponse jalien jalien-root jdk jemalloc jq json-c kfparticle lhapdf libffi libinfologger libjalieno2 libpng libunwind libuv libwebsockets libxml2 lz4 lzma mcsteplogger mlmodels monitoring mpfr ms_gsl o2 o2dpg o2pdpsuite o2physics o2sim odc onnxruntime openssl photos ppconsul protobuf pythia pythia6 python python-modules python-modules-list qualitycontrol rapidjson re2 root roounfold simulation sqlite starlight tauola tbb treelite utf8proc vc vecgeom vgm vmc xercesc xjalienfs xrootd xsimd zeromq zlib