Nix and LHCb

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Who am I?

- PhD student at Manchester working on LHCb
- Supposed to be working on analysis and velo alignment
- Generally interested in computing
- Before starting this work I tried a few things
    - Including packaging ROOT/XRootD with conda

Why this started?

- This started with analysis preservation in mind
    - Post-DaVinci environments can be tricky to share/preserve
    - Docker is great, but can't be used in most places
    - Must be something better
- Looked at various options, settled on Nix
- Nix could be more generally useful everywhere

What is Nix?

What is Nix?

- Nix is a “purely functional package manager”
    - Works with Linux and macOS
    - Can be used alongside other package managers
    - There is also a Linux distribution, NixOS

What is Nix?

- Nix is a “purely functional package manager”
- Source-based
    - *Binary caches* can be used to avoid compiling everything

What is Nix?

- Nix is a “purely functional package manager”
- Source-based
- Packages are built from *Nix expressions*
    - Typically $\mathcal{O}(10)$ lines long
    - Defined using a custom functional language
    - $\sim$14,000 package definitions available in nixpkgs

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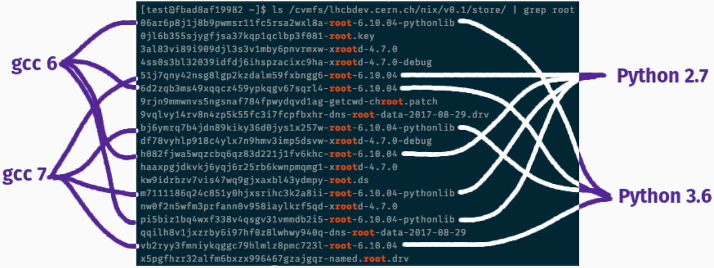
- Packages are built from *Nix expressions*
- Builds aim to be portable, reproducible and deterministic
- Lots more features available when used fully
  - NixOS
  - Single and multi user modes
  - Transactional approach to updates and configuration

How does Nix work?

- Everything is stored in `/nix/` (by default)
- Packages are kept in `/nix/store`
- Each package lives in a directory named by hash of it's dependencies
  - gcc6: `/nix/store/6d2zqb3ms49xqqcz459ypkqgv67sqrl4-root-6.10.04/`
  - gcc7: `/nix/store/h082fjwa5wqzcbq6qz83d221j1fv6khc-root-6.10.04/`
- Optionally packages can have multiple outputs
  - `bin`, `lib`, `python-lib`, ...



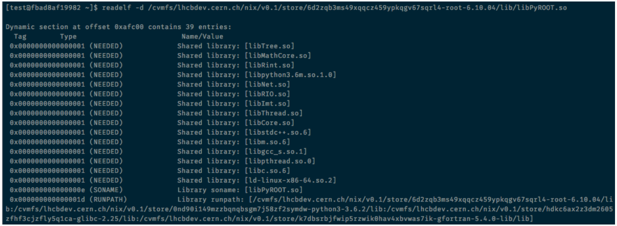
```
[test@fbad8af19982 ~]$ ls /cvmfs/lhcbdev.cern.ch/nix/v0.1/store/ | grep root
06ar6p8j1j8b9pwmsr11fc5rsa2wxl8a-root-6.10.04-pythonlib
0jl6b355sjygfjsa37kqp1qclbp3f081-root.key
3al83vi89i909djl3s3v1mby6pnvrmxw-xrootd-4.7.0
4ss0s3bl32039idfdj6ihspzacixc9ha-xrootd-4.7.0-debug
51j7qny42nsg8lgp2kzdalm59fxbngg6-root-6.10.04
6d2zqb3ms49xqqcz459ypkqgv67sqrl4-root-6.10.04
9rjn9mmwnvs5ngsnaf784fpwydqvd1ag-getcwd-chroot.patch
9vqlvy14rv8n4zp5k55fc3i7fcpfbxhr-dns-root-data-2017-08-29.drv
bj6ymrq7b4jdn89kiky36d0jys1x257w-root-6.10.04-pythonlib
df78vyhlp918c4ylx7n9hmv3imp5dsvw-xrootd-4.7.0-debug
h082fjwa5wqzcbq6qz83d221j1fv6khc-root-6.10.04
haaxpgjdkvkj6yqj6r25rb6kwnpmqmg1-xrootd-4.7.0
kw9idrbzv7vis47wq9gjxaxbl43ydmpy-root.ds
m7111186q24c851y0hjxsrihc3k2a8ii-root-6.10.04-pythonlib
nw0f2n5wfm3prfann0v958iaylkrf5qd-xrootd-4.7.0
pi5biz1bq4wxf338v4qsgv31vmmdb2i5-root-6.10.04-pythonlib
qqilh8v1jxzrby6i97hf0z8lwhwy940q-dns-root-data-2017-08-29
vb2ryy3fmniykqggc79hlmlz8pmc723l-root-6.10.04
x5pgfhzr32alfm6bxzx996467gzajgqr-named.root.drv
```

Nix expressions

- A collection of nix expressions is known as a *channel*
- Nixpkgs is the most common: `https://github.com/NixOS/nixpkgs` [1]

[1] There are also release channels at: `https://github.com/NixOS/nixpkgs-channels`

Nix expressions



```
[test@fbad8af19982 ~]$ readelf -d /cvmfs/lhcbdev.cern.ch/nix/v0.1/store/6d2zqb3ms49xqqcz459ypkqgv67sqrl4-root-6.10.04/lib/libPyROOT.so

Dynamic section at offset 0xafc00 contains 39 entries:
  Tag        Type                         Name/Value
 0x0000000000000001 (NEEDED)             Shared library: [libTree.so]
 0x0000000000000001 (NEEDED)             Shared library: [libMathCore.so]
 0x0000000000000001 (NEEDED)             Shared library: [libRint.so]
 0x0000000000000001 (NEEDED)             Shared library: [libpython3.6m.so.1.0]
 0x0000000000000001 (NEEDED)             Shared library: [libNet.so]
 0x0000000000000001 (NEEDED)             Shared library: [libRIO.so]
 0x0000000000000001 (NEEDED)             Shared library: [libImt.so]
 0x0000000000000001 (NEEDED)             Shared library: [libThread.so]
 0x0000000000000001 (NEEDED)             Shared library: [libCore.so]
 0x0000000000000001 (NEEDED)             Shared library: [libstdc++.so.6]
 0x0000000000000001 (NEEDED)             Shared library: [libm.so.6]
 0x0000000000000001 (NEEDED)             Shared library: [libgcc_s.so.1]
 0x0000000000000001 (NEEDED)             Shared library: [libpthread.so.0]
 0x0000000000000001 (NEEDED)             Shared library: [libc.so.6]
 0x0000000000000001 (NEEDED)             Shared library: [ld-linux-x86-64.so.2]
 0x000000000000000e (SONAME)             Library soname: [libPyROOT.so]
 0x000000000000001d (RUNPATH)            Library runpath: [/cvmfs/lhcbdev.cern.ch/nix/v0.1/store/6d2zqb3ms49xqqcz459ypkqgv67sqrl4-root-6.10.04/li
b:/cvmfs/lhcbdev.cern.ch/nix/v0.1/store/0nd90i149mzzbqnqbsgm7j58zf2symdw-python3-3.6.2/lib:/cvmfs/lhcbdev.cern.ch/nix/v0.1/store/hdkc6ax2z3dm2605
zfhf3cjzfly5q1ca-glibc-2.25/lib:/cvmfs/lhcbdev.cern.ch/nix/v0.1/store/k7dbsrbjfwip5rzwik0hav4xbvwas7ik-gfortran-5.4.0-lib/lib]
```

- A collection of nix expressions is known as a *channel*
- Nixpkgs is the most common: `https://github.com/NixOS/nixpkgs` [1]
- Nixpkgs also provides helper functions
    - `buildEnv`: Makes a meta package of symlinks
    - `fetchurl`/`fetchgit`/`fetchpatch`/`fetchcvs`/`fetchipfs`
    - `stdenv.mkDerivation`
        - Uses the standard environment to run a `genericBuild`
        - Sets up linker flags and `RUNPATH`
        - Rewrites the interpreter paths of shell scripts to `/nix/store/...`
        - Also uses test suites for many packages

[1] There are also release channels at: `https://github.com/NixOS/nixpkgs-channels`

A Nix expression for Gaudi

```nix
{ stdenv, fetchurl, fetchpatch, boost, clhep, cmake, cppunit, gperftools
, heppdt, jemalloc, libunwind, python, tbb, utillinux, xercesc, zlib
, ninja, root, gdb, aida, gsl, libpng }:

stdenv.mkDerivation rec {
  name = "gaudi-${version}";
  version = "v29r0";

  src = fetchurl {
    url = "https://gitlab.cern.ch/gaudi/Gaudi/repository/${version}/archive.tar.gz";
    sha256 = "1ijdq1l8rscwij9hgyzrlvga1qg7b0csx76wcd76x3yli8bc766b";
  };

  buildInputs = [
    cmake python gdb aida ninja root boost clhep cppunit gperftools heppdt
    jemalloc libunwind tbb utillinux xercesc zlib gsl libpng
  ];

  patches = [ ./fix-profiling.patch ];

  cmakeFlags = [
    "-GNinja"
  ];

  enableParallelBuilding = true;

  meta = {
    homepage = https://gaudi.web.cern.ch/gaudi/;
    description = "A basis for HEP experiment frameworks";
    platforms = stdenv.lib.platforms.unix;
    maintainers = with stdenv.lib.maintainers; [ chrisburr ];
  };
}
```

What have I done?

Moving the nix store directory

- Installed Nix inside docker without cvmfs mounted
- Built Nix changing `/nix/` to `/cvmfs/lhcbdev.cern.ch/nix/`

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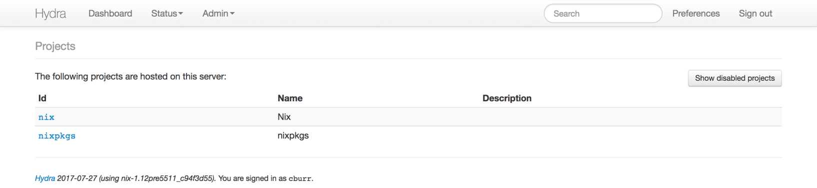
- Installed Nix inside docker without cvmfs mounted
- Built Nix changing `/nix/` to `/cvmfs/lhcbdev.cern.ch/nix/`
- Built Nix again....
- And it works!!!!
- But the official binary cache can't be used anymore...
- Have since created a gitlab group: `https://gitlab.cern.ch/lhcb-nix/`
    - `bootstrap`: Use GitLab CI to build nix with a custom store directory
    - Also contains forks of `hydra`, `nix` and `nixpkgs`

Hydra build "farm"



Projects

The following projects are hosted on this server:

Id	Name	Description
`nix`	Nix	
`nixpkgs`	nixpkgs	

Hydra 2017-07-27 (using nix-1.12pre5511_c94f3d55). You are signed in as `cburr`.

- Set up an instance of Hydra[2] on openstack: `http://lhcb-hydra.cern.ch:3000/`
- Took less than an hour to get my first build Including setting up PostgreSQL!
    - Uses the local machine for builds
- Since moved to using **DBoD** and GitLab CI to build a container

[2] `https://nixos.org/hydra/`

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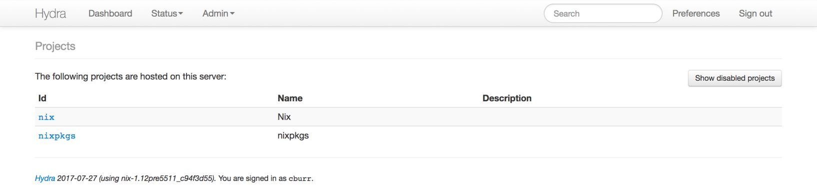

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- Setting up an extra worker was trivial
    - Just need to be able to SSH to a machine with Nix
    - Docker container on **`lblhcbpr3`** with my build of Nix installed

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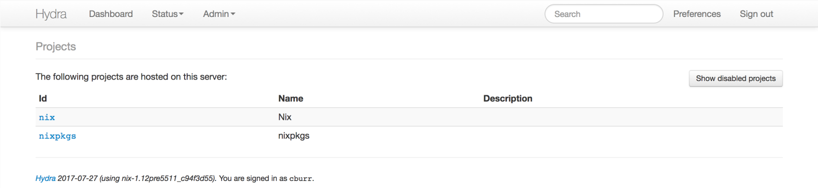

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  - Just need to be able to SSH to a machine with Nix
  - Docker container on `lblhcbpr3` with my build of Nix installed
- Support for slaves with different architectures or extra features (AVX?)

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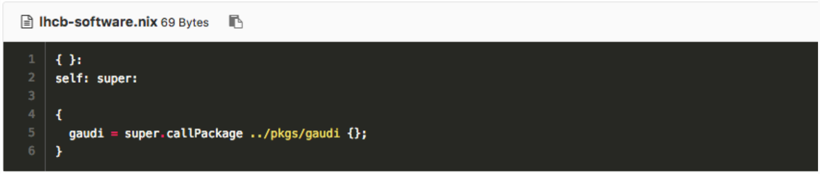
nixpkgs overlays

- nixpkgs has a concept of overlays that are applied the main nixpkgs



lhcb-software.nix 69 Bytes

```nix
{ }:
self: super:

{
  gaudi = super.callPackage ../pkgs/gaudi {};
}
```

nixpkgs overlays

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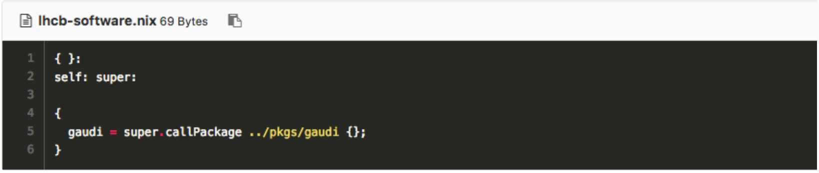

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```
{ }:
self: super:

{
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}
```
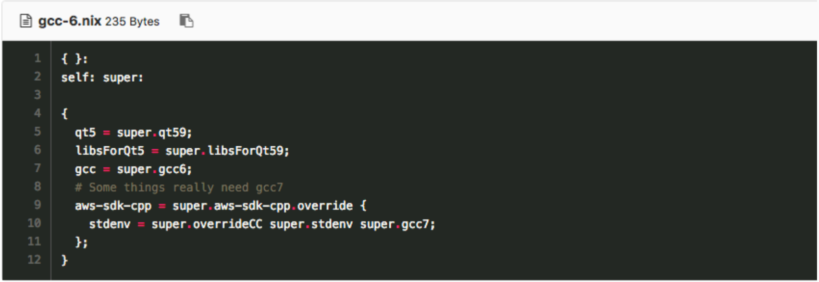

- Can also override existing packages or package arguments

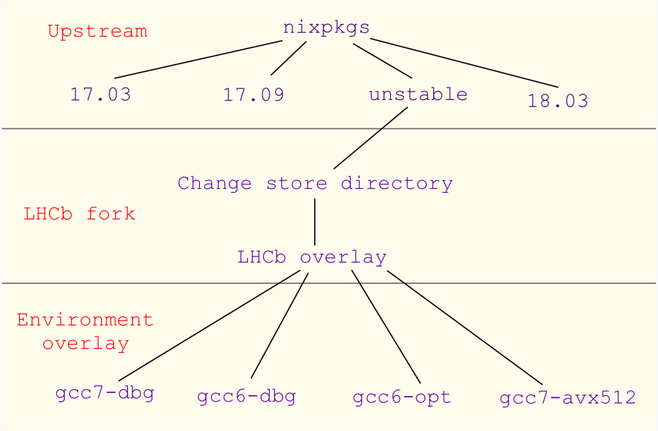


gcc-6.nix 235 Bytes

```
{ }:
self: super:

{
  qt5 = super.qt59;
  libsForQt5 = super.libsForQt59;
  gcc = super.gcc6;
  # Some things really need gcc7
  aws-sdk-cpp = super.aws-sdk-cpp.override {
    stdenv = super.overrideCC super.stdenv super.gcc7;
  };
}
```

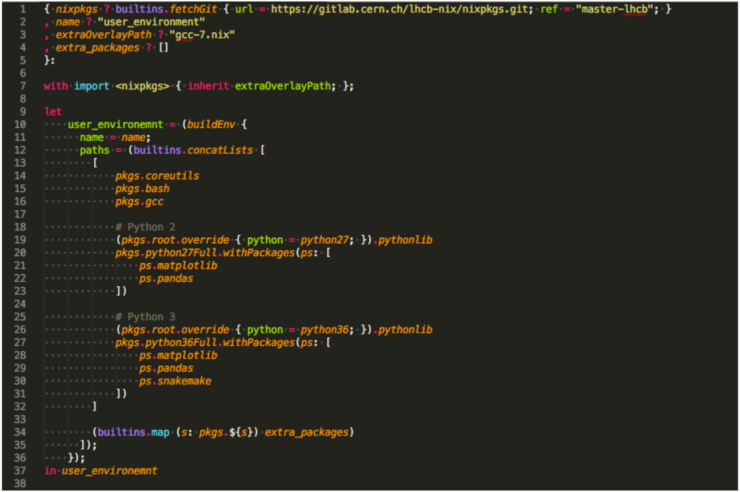
LHCb version of `nixpkgs`

- Use first overlay to add packages that are unsuitable for upstream
- Second overlay is an argument to `nixpkgs` to set the environment



Creating environments

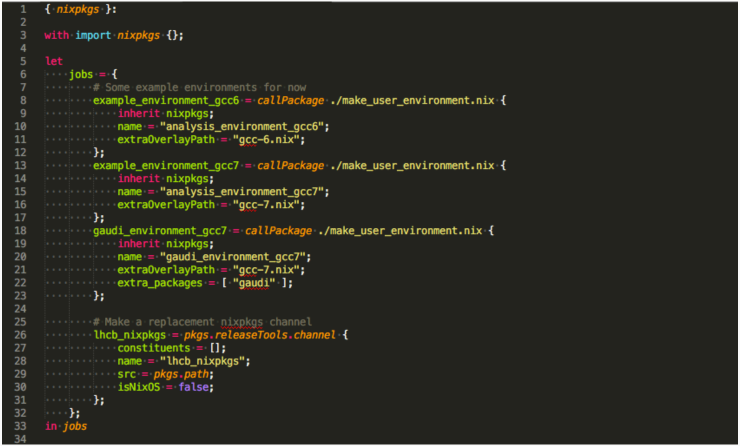
- nixpkgs can be used to create environments using buildEnv
    - Symlinked to the store directory, similar to an LCG view
- To give a short but comprehensive example:



```
{ nixpkgs ? builtins.fetchGit { url = https://gitlab.cern.ch/lhcb-nix/nixpkgs.git; ref = "master-lhcb"; }
, name ? "user_environment"
, extraOverlayPath ? "gcc-7.nix"
, extra_packages ? []
}:

with import <nixpkgs> { inherit extraOverlayPath; };

let
    user_environemnt = (buildEnv {
      name = name;
      paths = (builtins.concatLists [
        [
            pkgs.coreutils
            pkgs.bash
            pkgs.gcc

            # Python 2
            (pkgs.root.override { python = python27; }).pythonlib
            pkgs.python27Full.withPackages(ps: [
                ps.matplotlib
                ps.pandas
            ])

            # Python 3
            (pkgs.root.override { python = python36; }).pythonlib
            pkgs.python36Full.withPackages(ps: [
                ps.matplotlib
                ps.pandas
                ps.snakemake
            ])
        ]

        (builtins.map (s: pkgs.${s}) extra_packages)
      ]);
    });
in user_environemnt

```

Creating environments

- You can then define multiple versions with different arguments
- I've created three as an example:



```
{ nixpkgs }:

with import nixpkgs {};

let
    jobs = {
        # Some example environments for now
        example_environment_gcc6 = callPackage ./make_user_environment.nix {
            inherit nixpkgs;
            name = "analysis_environment_gcc6";
            extraOverlayPath = "gcc-6.nix";
        };
        example_environment_gcc7 = callPackage ./make_user_environment.nix {
            inherit nixpkgs;
            name = "analysis_environment_gcc7";
            extraOverlayPath = "gcc-7.nix";
        };
        gaudi_environment_gcc7 = callPackage ./make_user_environment.nix {
            inherit nixpkgs;
            name = "gaudi_environment_gcc7";
            extraOverlayPath = "gcc-7.nix";
            extra_packages = [ "gaudi" ];
        };

        # Make a replacement nixpkgs channel
        lhcb_nixpkgs = pkgs.releaseTools.channel {
            constituents = [];
            name = "lhcb_nixpkgs";
            src = pkgs.path;
            isNixOS = false;
        };
    };
in jobs
```

- Full example stored at: `https://gitlab.cern.ch/lhcb-nix/lhcb-environments`
- Built in the `lhcb-environments` project on hydra

The example environments

- As most of the work is done upstream adding packages is easy
- As these examples are designed to replace PATH entirely they contain:
  - Shells: `bash/zsh/tcsh/dash`
  - Standard utilities: `coreutils/man/grep/tar/findutils/rsync/...`
  - Text editors: `nano/vim/neovim/atom`
  - Version control: `git/svn/hg`

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  - Debugging: `gdb/lldb/valgrind`
  - TexLive 2017

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  - Python 2.7 with `matplotlib/numpy/pandas/nose/jupyter/...`
  - Python 3.6 with `matplotlib/numpy/pandas/snakemake/...`
  - XRootD with Python 2.7 and 3.6 bindings
  - ROOT* with Python 2.7 and 3.6 bindings

Try it for yourself in docker!

Try it for yourself in docker! (CERN only due to firewall)

- Install Nix:

```
docker run --rm -it centos:7 bash
useradd test
yum install -y bzip2
mkdir -p -m 0755 /cvmfs/lhcbdev.cern.ch/nix
chown test /cvmfs/lhcbdev.cern.ch/nix
cd /home/test
su test bash -c "curl -LO https://chrisburr.me/lhcb-nix-2.0/nix-2.0-2018_03_20-x86_64-linux.tar.bz2"
su test bash -c "curl https://chrisburr.me/lhcb-nix-2.0/install | sh"
```

- Install one (or more) of the environments in any directory:

  `example_environment_gcc6`/`example_environment_gcc7`/`gaudi_environment_gcc7`

```
su test
. /home/test/.nix-profile/etc/profile.d/nix.sh
export LC_ALL=en_US.utf-8
export LANG=en_US.utf-8

mkdir -p "/cvmfs/lhcbdev.cern.ch/nix/environments/"
export LHCB_NIX_ENV_DIR="/cvmfs/lhcbdev.cern.ch/nix/environments/analysis_environment_gcc7"
nix-env -ir analysis_environment_gcc7 --profile "${LHCB_NIX_ENV_DIR}" -Q -j8
```

- Set `PATH` and run!

```
su test
export LHCB_NIX_ENV_DIR="/cvmfs/lhcbdev.cern.ch/nix/environments/analysis_environment_gcc7"
export PATH="${LHCB_NIX_ENV_DIR}/bin"
export CMAKE_PREFIX_PATH="${LHCB_NIX_ENV_DIR}"
export NIX_SSL_CERT_FILE=/etc/ssl/certs/ca-bundle.crt
bash
```

A few limitations of this setup

- Downloads are slow:
    - The binary cache is currently compressed on the fly by hydra
    - There is a setting to copy them to a directory/AWS/..
    - This can then be hosted on any web server
    - Plus packages are then signed automatically
- Package signatures aren't checked (see above)
- Some packages have issues being built inside docker containers

My thoughts...

Why use Nix?

- Software built should be able to run on “any” flavour of Linux
  - Example works with CentOS 6, 7 and Ubuntu
  - Darwin should be fairly easy to add
  - Experimental support for AArch64

Why use Nix?

- Software built should be able to run on “any” flavour of Linux
- Simpler environments
    - No more (ab)use of `LD_LIBRARY_PATH` or `PYTHON_PATH`
    - Software with conflicting dependencies can be used at the same time

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- Huge number of packages definitions already written ∼14,000
    - Adding new software to an environment is a one line change

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- Software built should be able to run on “any” flavour of Linux
- Simpler environments
- Huge number of packages definitions already written ∼14,000
- Adding new package definitions is straight forward
  - The standard builder already works with most build systems
  - `RUNPATH` and other paths are set automagically
  - Building Gaudi was trivial
    (once I had written definitions for all of it’s HEP specific dependencies...)
    (and fixed a bug? in the CMake config of the profiling module...)

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- Adding new package definitions is straight forward
- Active community, lots of very helpful experts on IRC

What isn't so good?

- Documentation is lacking some places
    - But it's rapidly improving
    - Figuring things out from the source isn't too difficult

What isn’t so good?

- Documentation is lacking some places
- The Nix expression language has a steep learning curve
  - I had never used a functional language like Haskell
  - Might have been easier if I had
  - Doesn’t matter simple things like writing packages

What isn’t so good?

- Documentation is lacking some places
- The Nix expression language has a steep learning curve
- Independence from the host system isn’t perfect
    - I’ve read about issues with OpenGL/graphics drivers
    - Kernel
    - Can’t be worse than what already exists

What isn't so good?

- Documentation is lacking some places
- The Nix expression language has a steep learning curve
- Independence from the host system isn't perfect
- Sometimes reproducible builds aren't reproducible
    - Only seen this happen due to remote files being removed/changed
    - So long as the original nix store is kept there is always a copy

Conclusions

- Nix is awesome!
- I can see a lot of benefits and potential uses
  - Could avoid issues with missing or conflicting dependencies
  - Defining extra environments is easy (per analysis?/distributable?)
  - Can update old environments where needed (XRootD?)
- Useful resources and some other details in backup

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Any Questions?

Useful resources

Documentation:

- Introduction to Nix: `https://nixos.org/nixos/nix-pills/`
- Nix manual: `https://nixos.org/nix/manual/`
- Nixpkgs manual: `https://nixos.org/nixpkgs/manual/`

Python packages

- `PYTHON_PATH` isn’t ideal as it is used by all Python versions
- `sitecustomize.py` is aimed for this purpose
    - Uses `$LHCB_NIX_ENV_DIR/lib/pythonX.Y/site-packages/`
- ROOT can’t be built with simultaneous Python 2 and 3 support
    - Instead make the Python library a separate package
    - Each is then loaded from `lib/pythonX.Y/site-packages`
    - Using `TPython` from the `root` REPL uses Python 2

Debug symbols

- Stripped and deleted by default
- `stdenv.mkDerivation` has an option `separateDebugInfo`
- Makes a `-debug` package containing `lib/debug/.build-id/XX/YYYY`
- Can be loaded in GDB by modifying ~`/.gdbinit` to contain:
    - `set debug-file-directory ENV_DIR/lib/debug`
    - There are probably other methods available