Particle Physics On The Couch:

Using CouchDB To Help Unravel The Mysteries Of The Universe

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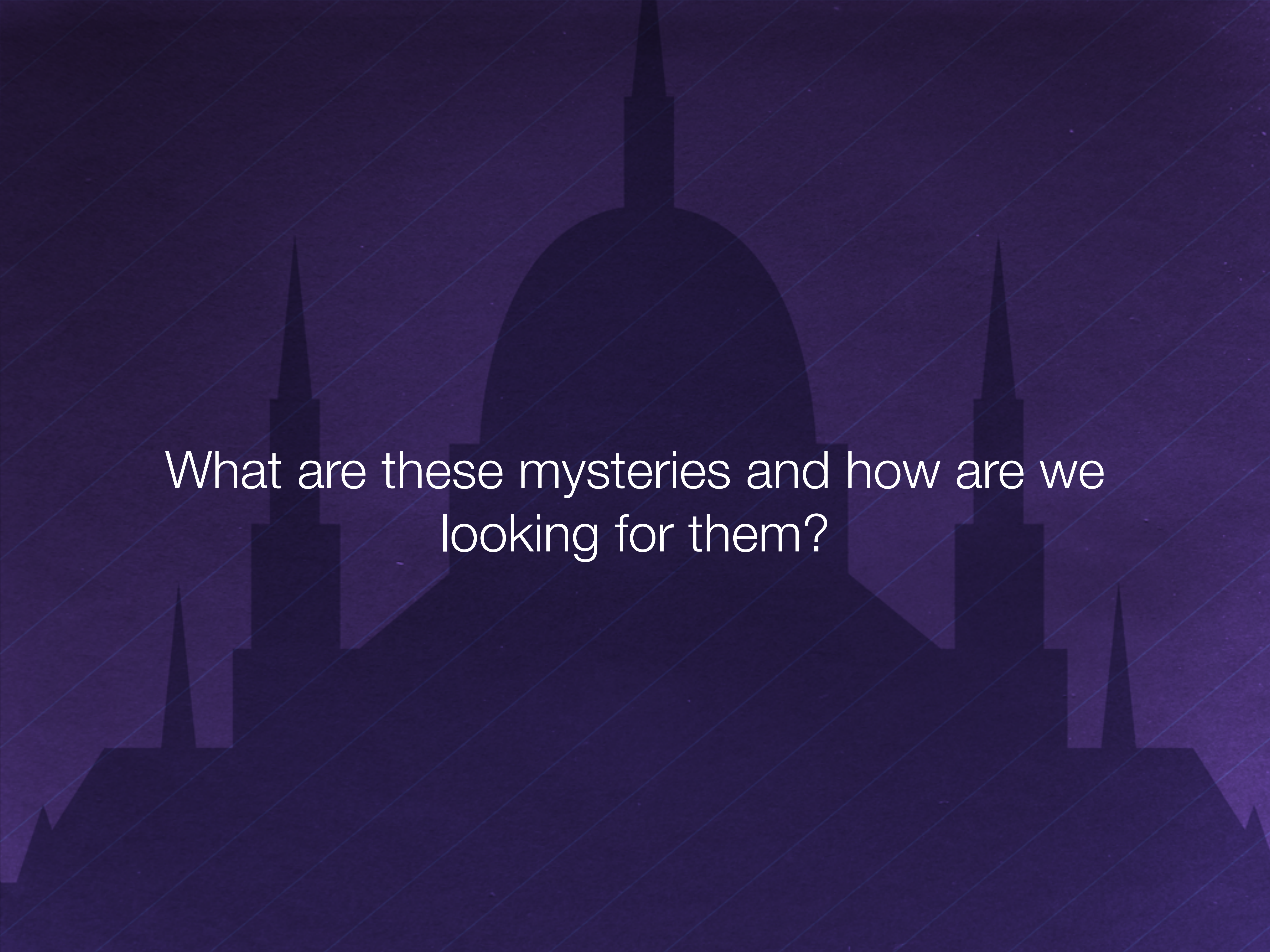
CORINTHIA HOTEL
BUDAPEST, HUNGARY
NOVEMBER 17-21, 2014



What are these mysteries and how are we looking for them?

Back to the beginning…

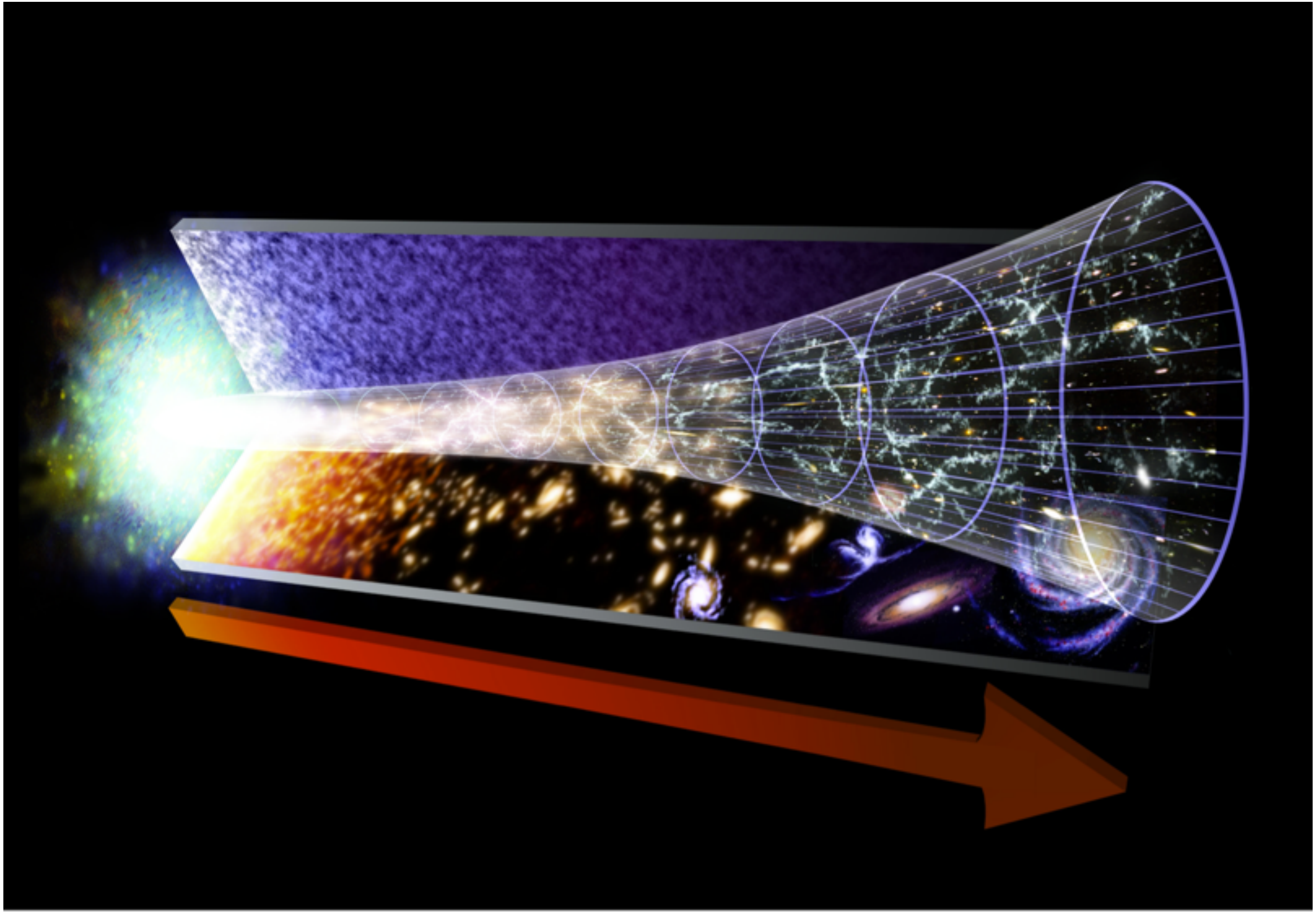
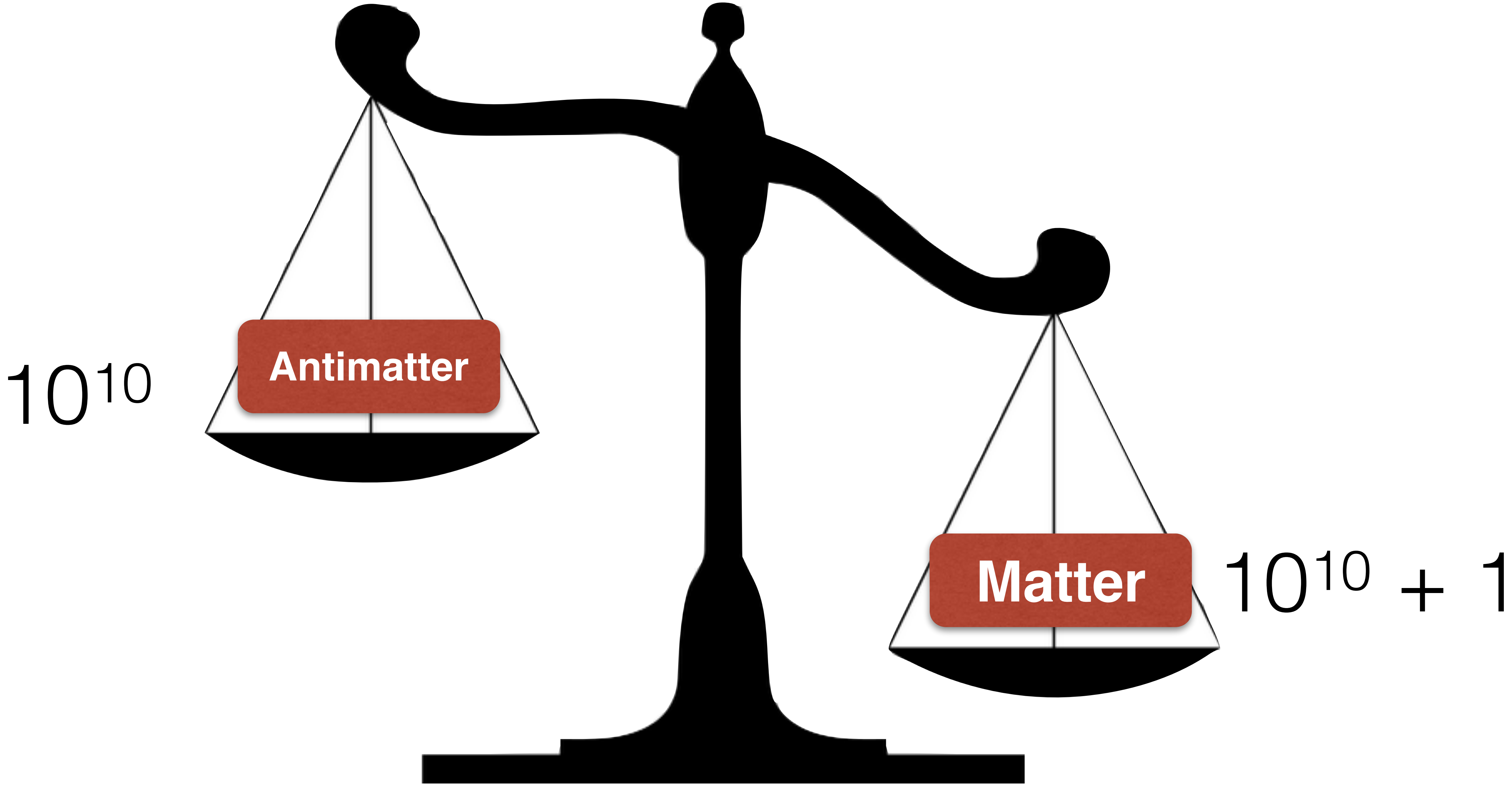


Image: NASA/GSFC

The difference between matter and anti-matter was tiny…



10^{10}

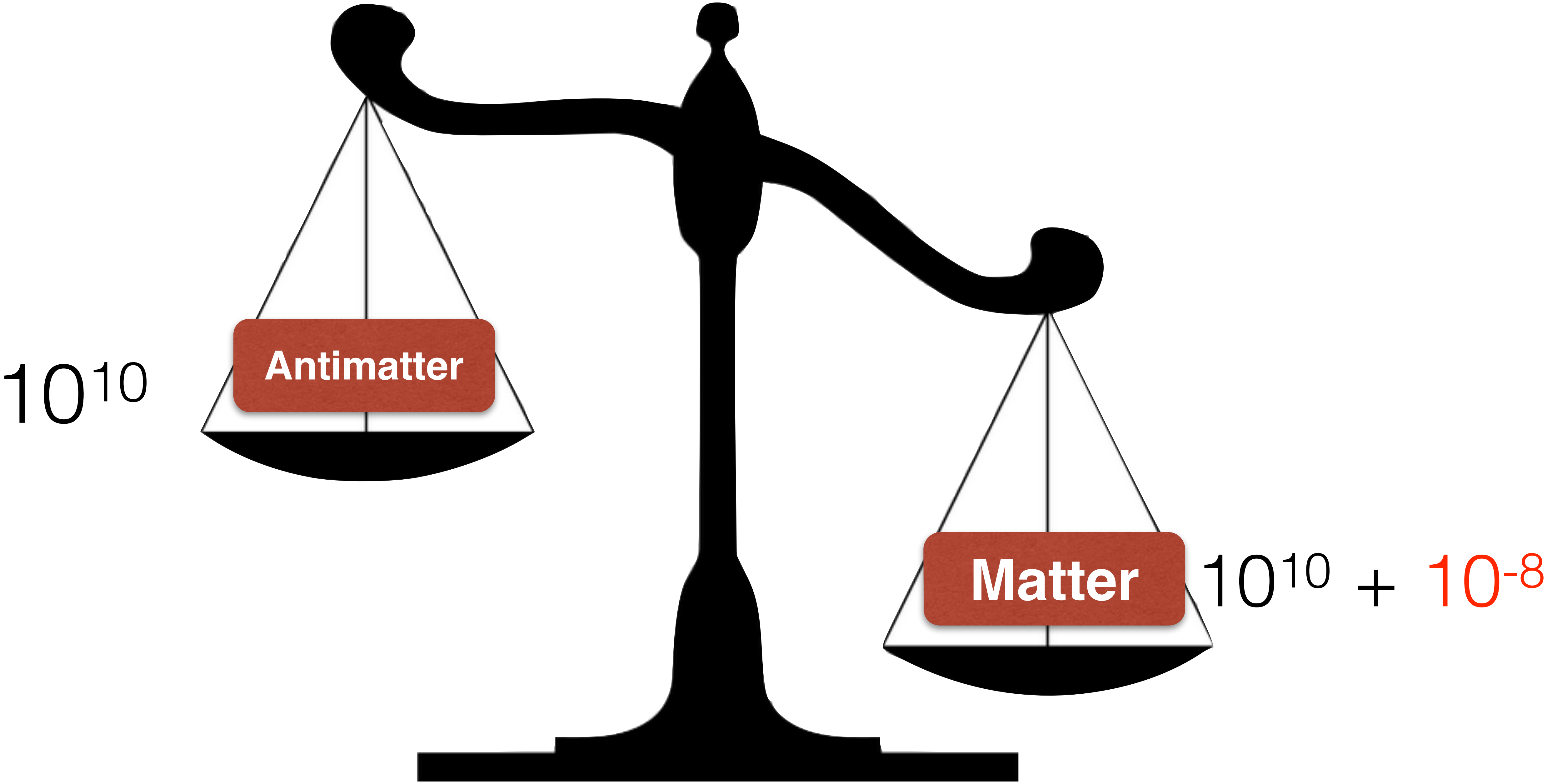
Antimatter

Matter

$10^{10} + 1$

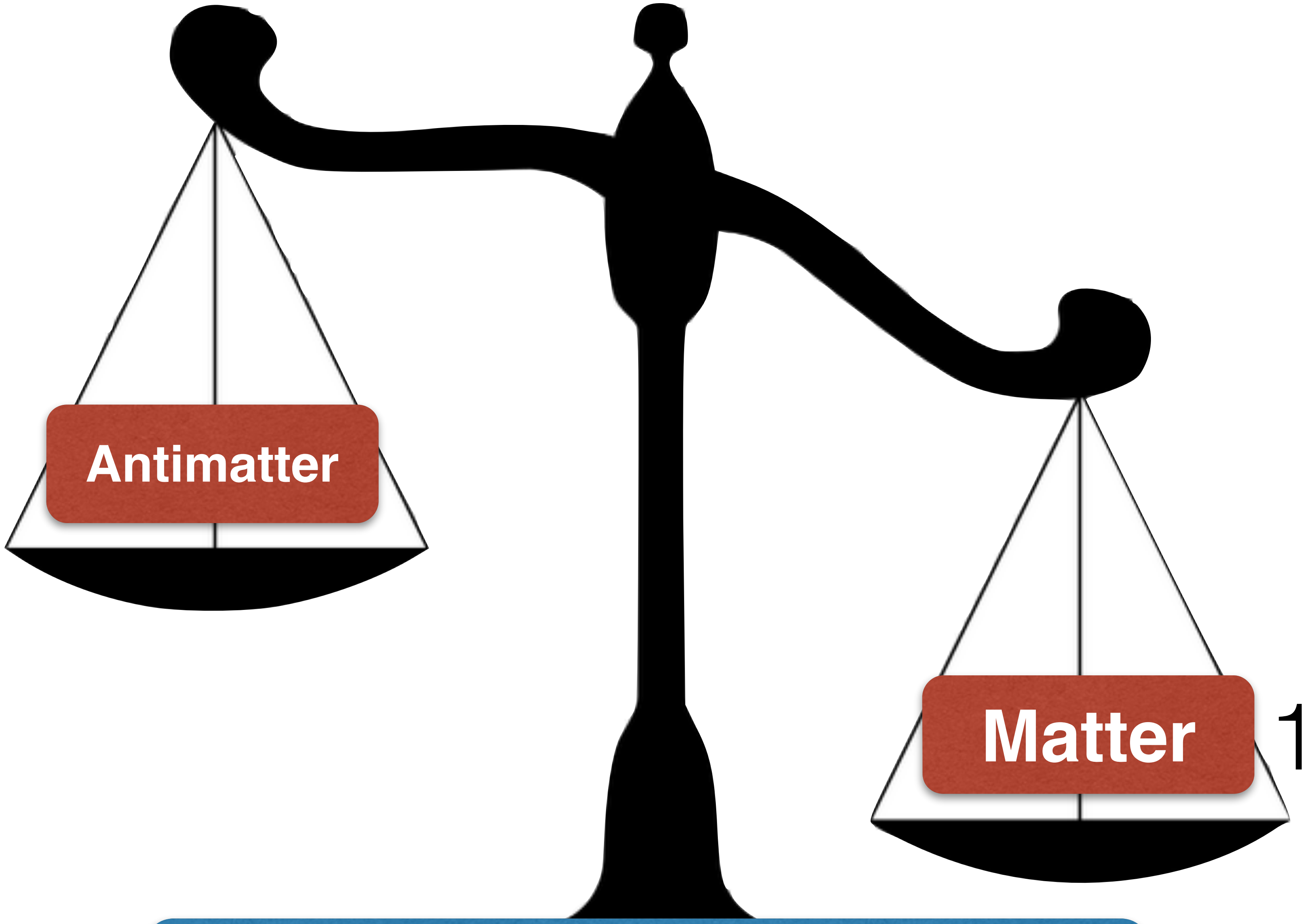
‘right after’ the Big Bang

… but we can only explain



… but we can only explain

10^{10}



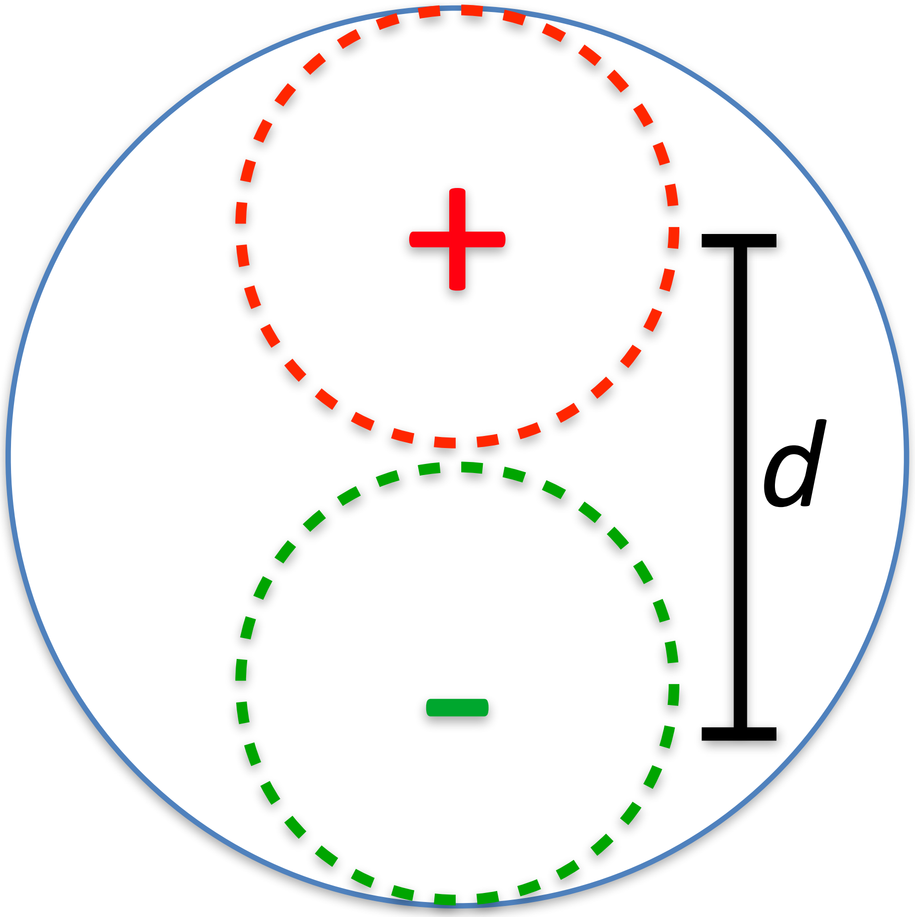
$10^{10} + 10^{-8}$

$10^{-8} < 1$!

neutrons to the rescue!

We search for a particular characteristic of the neutron:

neutron Electric Dipole Moment (nEDM):
a (tiny!) separation of electrical charge within the neutron



Discovery of this helps to solve the matter/anti-matter problem

How small is *d*?

If we blow up the neutron to the size of the earth…

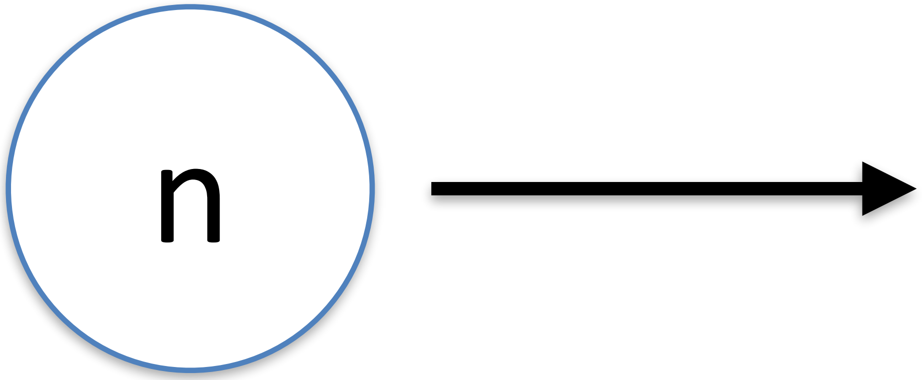
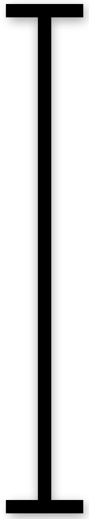
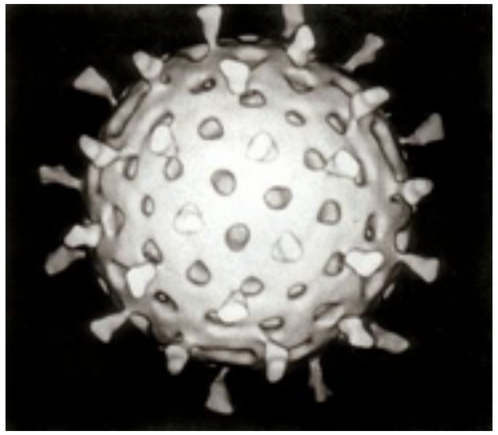


Image: NASA/NOAA/GSFC/Suomi NPP/VIIRS/Norman Kuring



d <



Virus

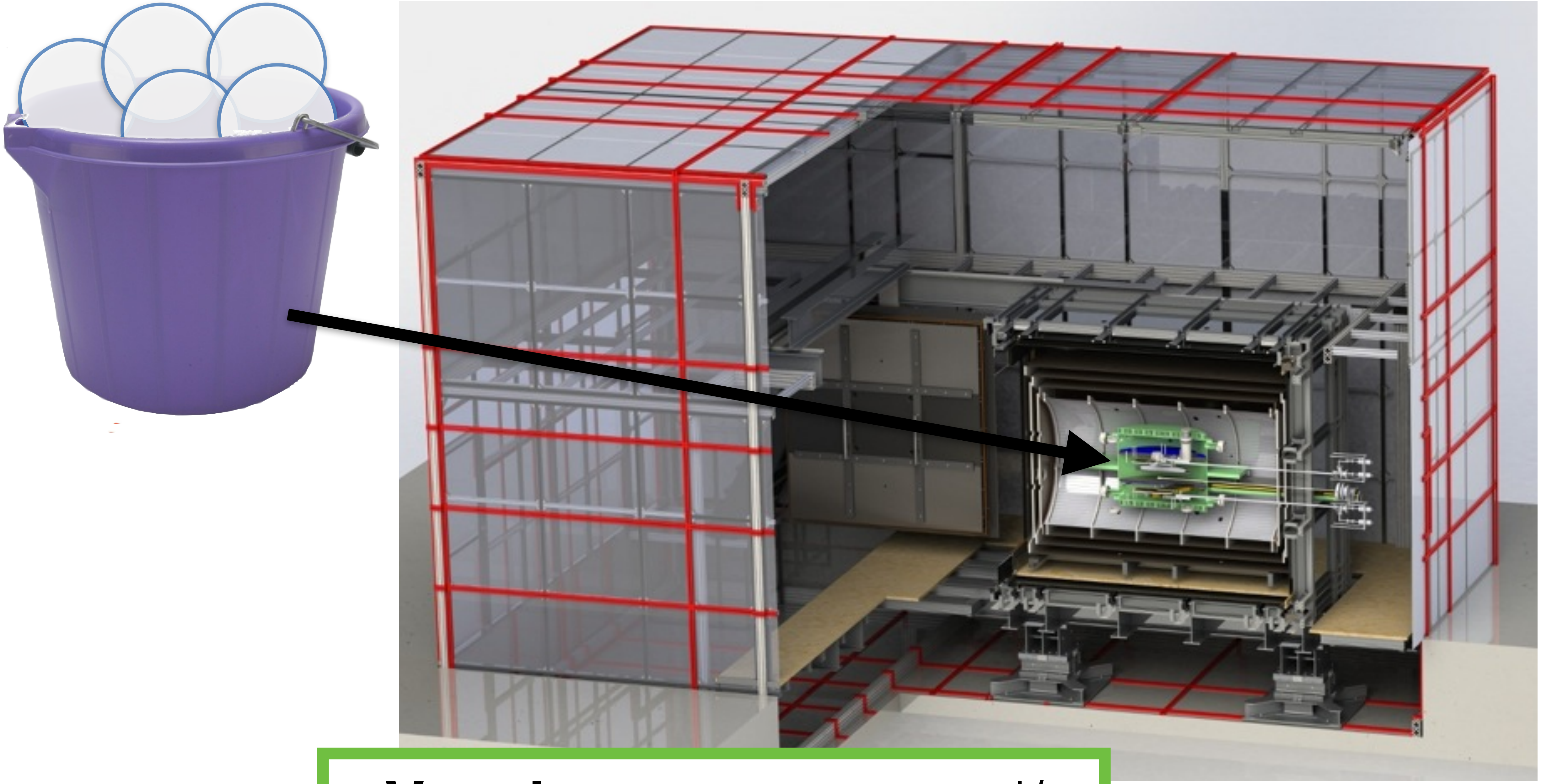
Image: Wikipedia, Graham Colm

How do we find it?

… with a bucket full of neutrons

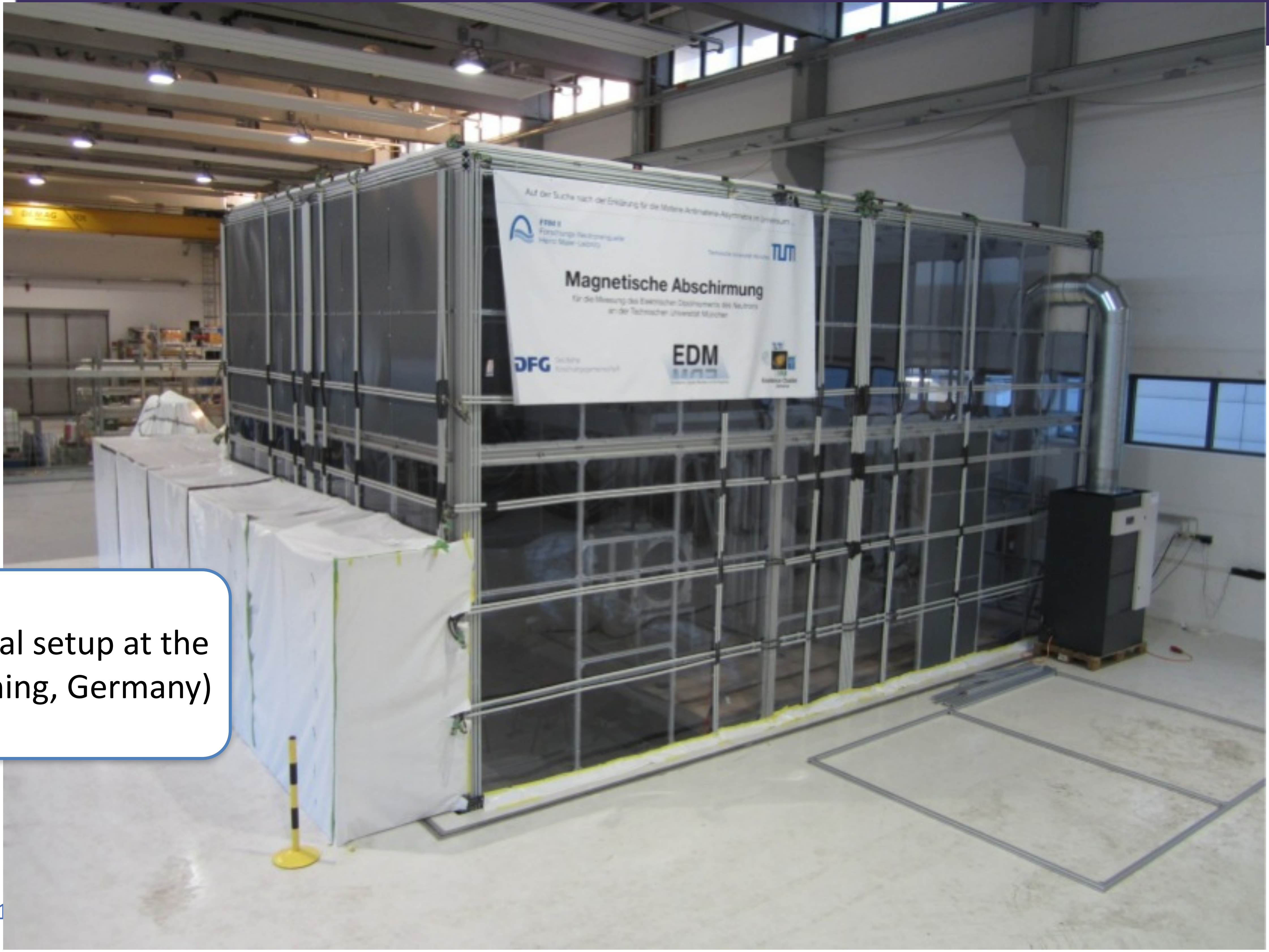
(we can literally store neutrons in a bottle for ~100s of seconds, and then investigate them)

It’s a bit more complicated than that…



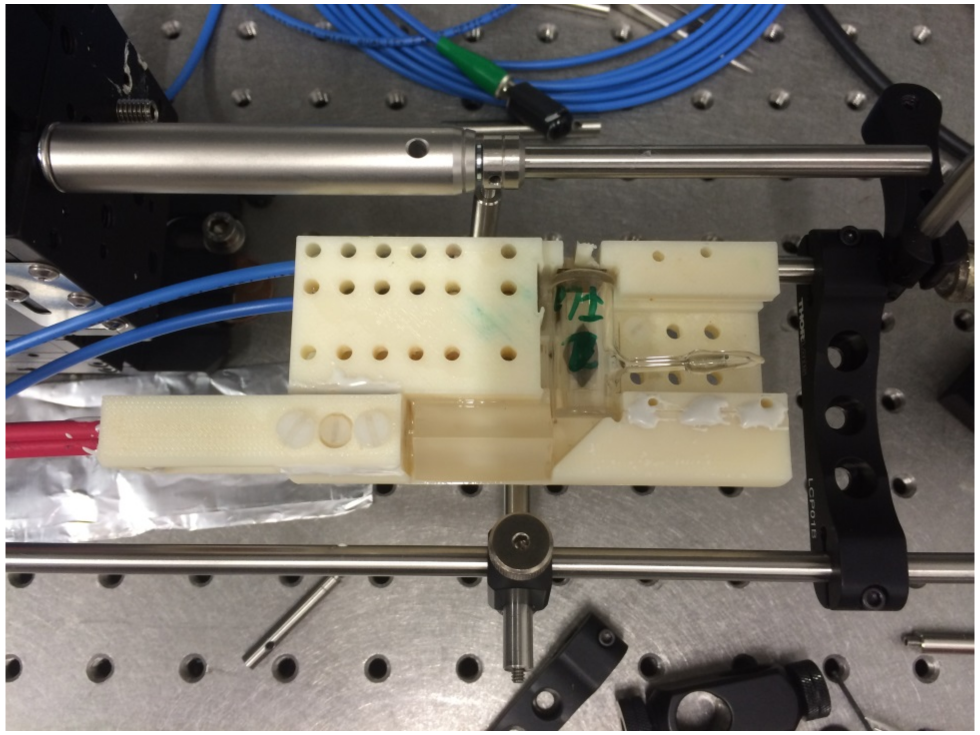
Very important: control/ understand magnetic fields

It’s a bit more complicated than that…

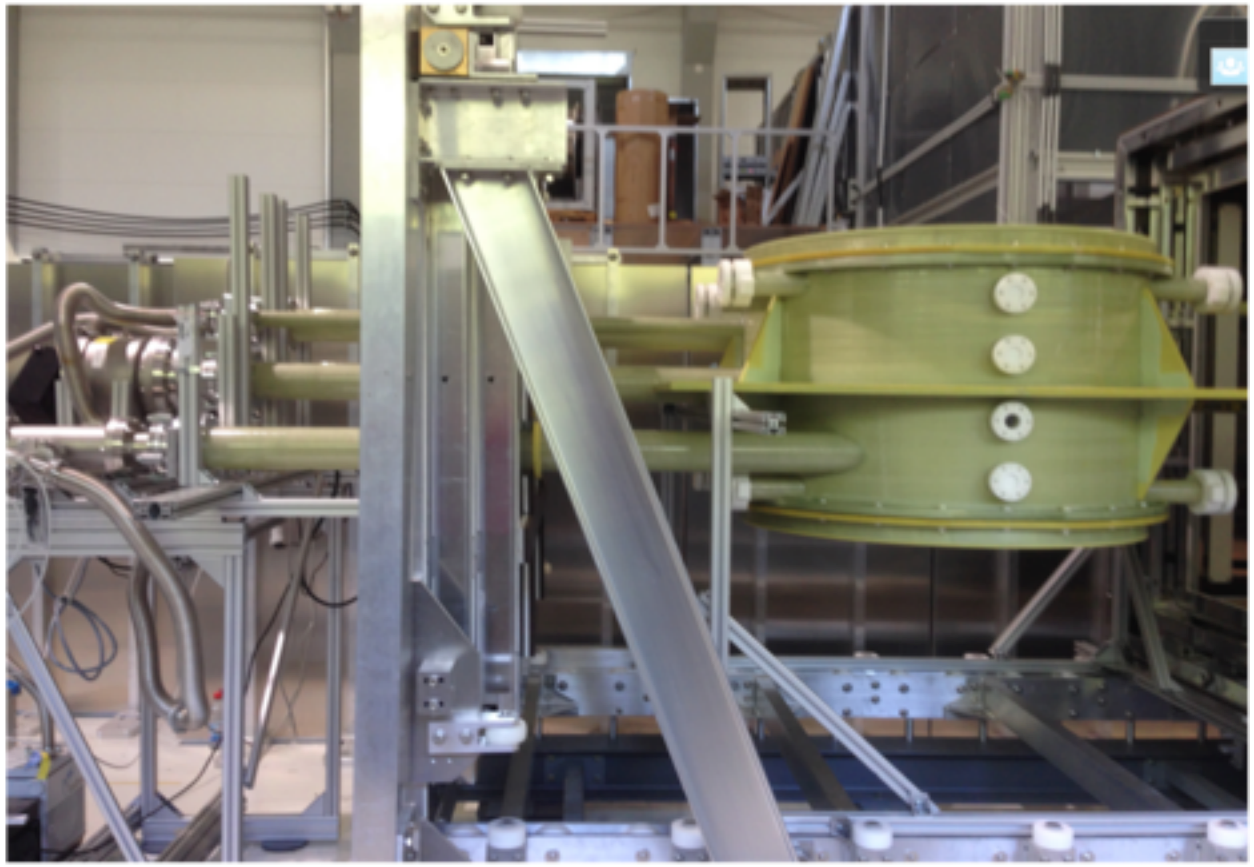

Auf der Suche nach der Erklärung für die Materie-Antimaterie-Asymmetrie im Universum
FRM II
Forschungs-Neutronenquelle Heinz Maier-Leibnitz
TUM
Magnetische Abschirmung
für die Messung des Elektrischen Dipolmoments des Neutrons an der Technischen Universität München
DFG
Deutsche Forschungsgemeinschaft
EDM

Experimental setup at the TUM (Garching, Germany)

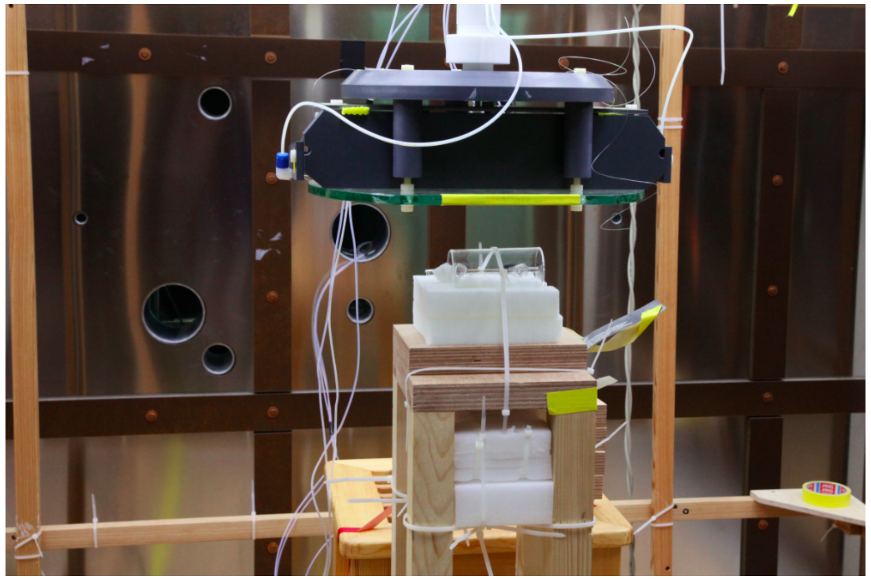
It’s a bit more complicated than that…



Magnetometer (Cs laser)



The neutron chamber



“Robot” for mapping out magnetic fields

It’s a bit more complicated than that…

- **Many different subsystems:**
  - Cs Laser + magnetometry system 🐧
  - Hg Laser + co-magnetometer 🍓
  - External magnetometry 🐧
  - Active coil earth magnetic field compensation
  - Temperature/humidity monitoring ∞
  - Neutron detection 🐧
  - Valve monitoring/control 🍓
  - B0 coil/current controls 🍓 🐧
  - Vacuum monitoring 🍓
  - Nuclear Magnetic Resonance System 🐧
  - SQUID ⊞
  - Degaussing ⊞
  - etc…

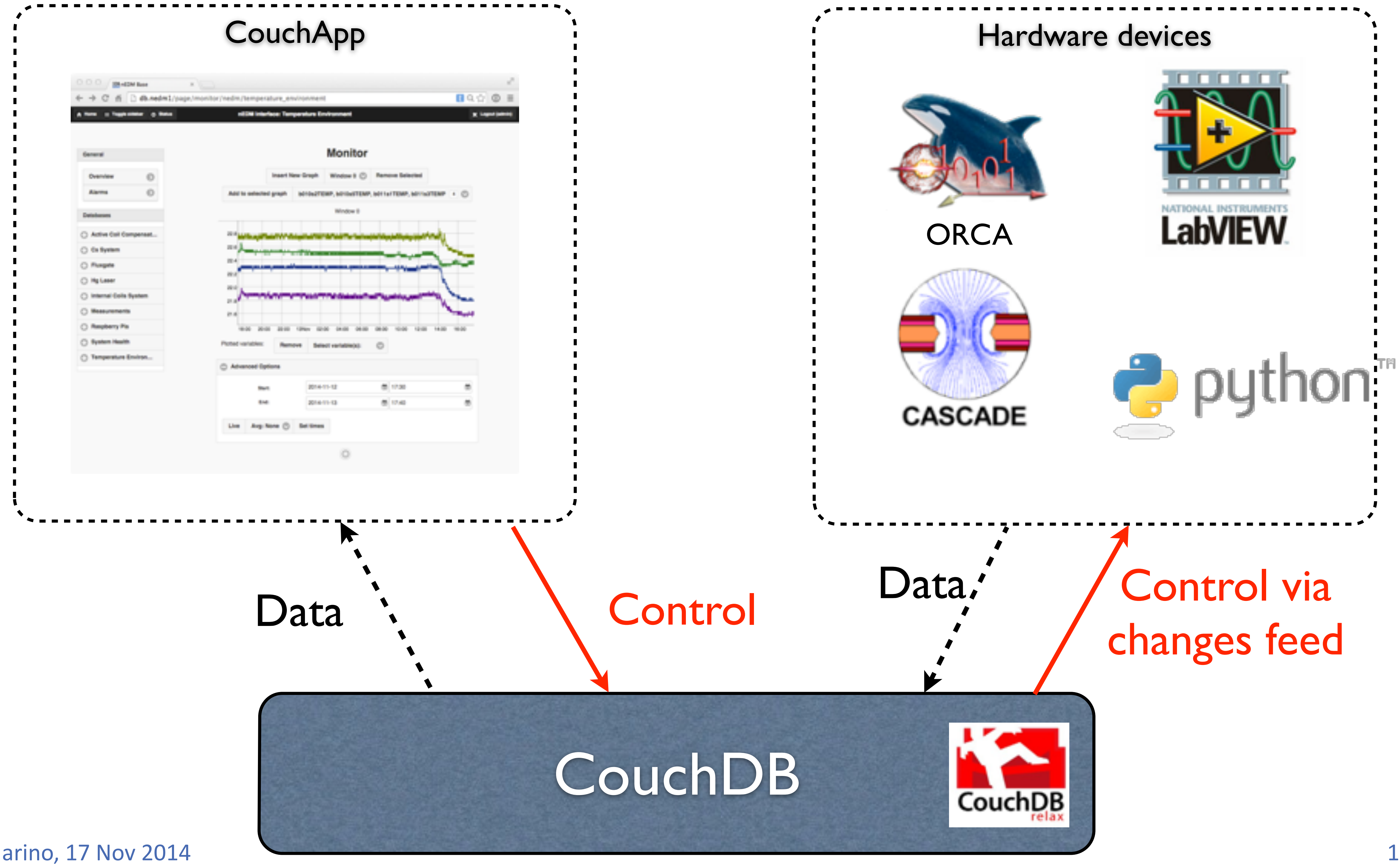
All of these systems take and write data

Some of them must also be controlled

A lot of independent hardware systems, in general with very different requirements/ dependencies/languages, etc.

But they all need to play together!

Basic concept



How do we use CouchDB’s features?

Why CouchDB?

RESTful Interface

= small hurdle

Arduinos

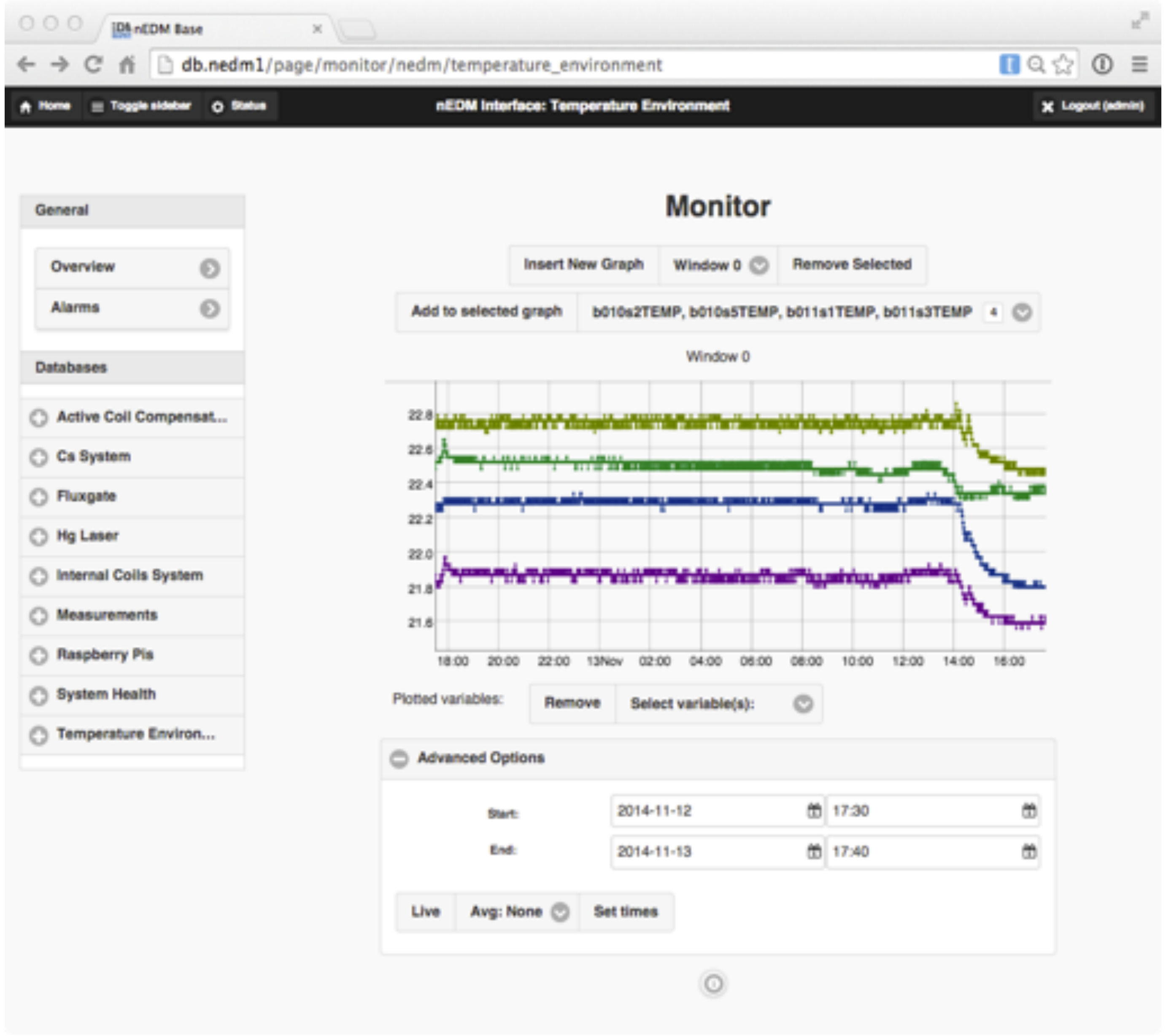
Raspberry Pi

VMEbus

Why CouchDB?

RESTful Interface

Embedded web app



db.nedm1/page/monitor/nedm/temperature_environment

b010s2TEMP, b010s5TEMP, b011s1TEMP, b011s3TEMP 4

Start: 2014-11-12 17:30

End: 2014-11-13 17:40

Control/monitor all sub-systems from a browser.
Automatic cross-platform (-device)* support

Why CouchDB?

RESTful Interface

Embedded web app

Simplicity/ scalability

Every subsystem is a database,

- allowing granularity of control (only some users get the rights to change a particular system)
- systems are kept separate
- new system = new database
- should be easy (fun!) for students (undergrads and PhDs) to build

Why CouchDB?

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Why CouchDB?

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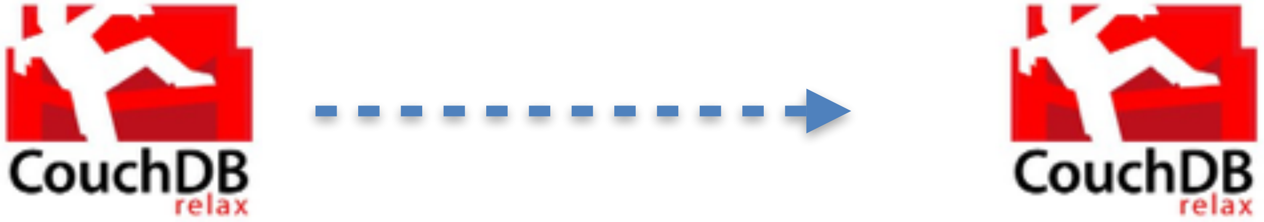
Simplicity/ scalability

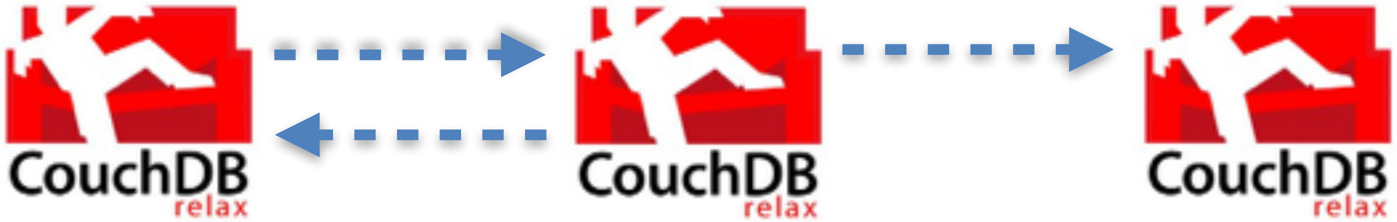
Replication

Twofold:



Partial replication (a subset of databases/subsystems)

Deploying of a test apparatus at another site, etc.



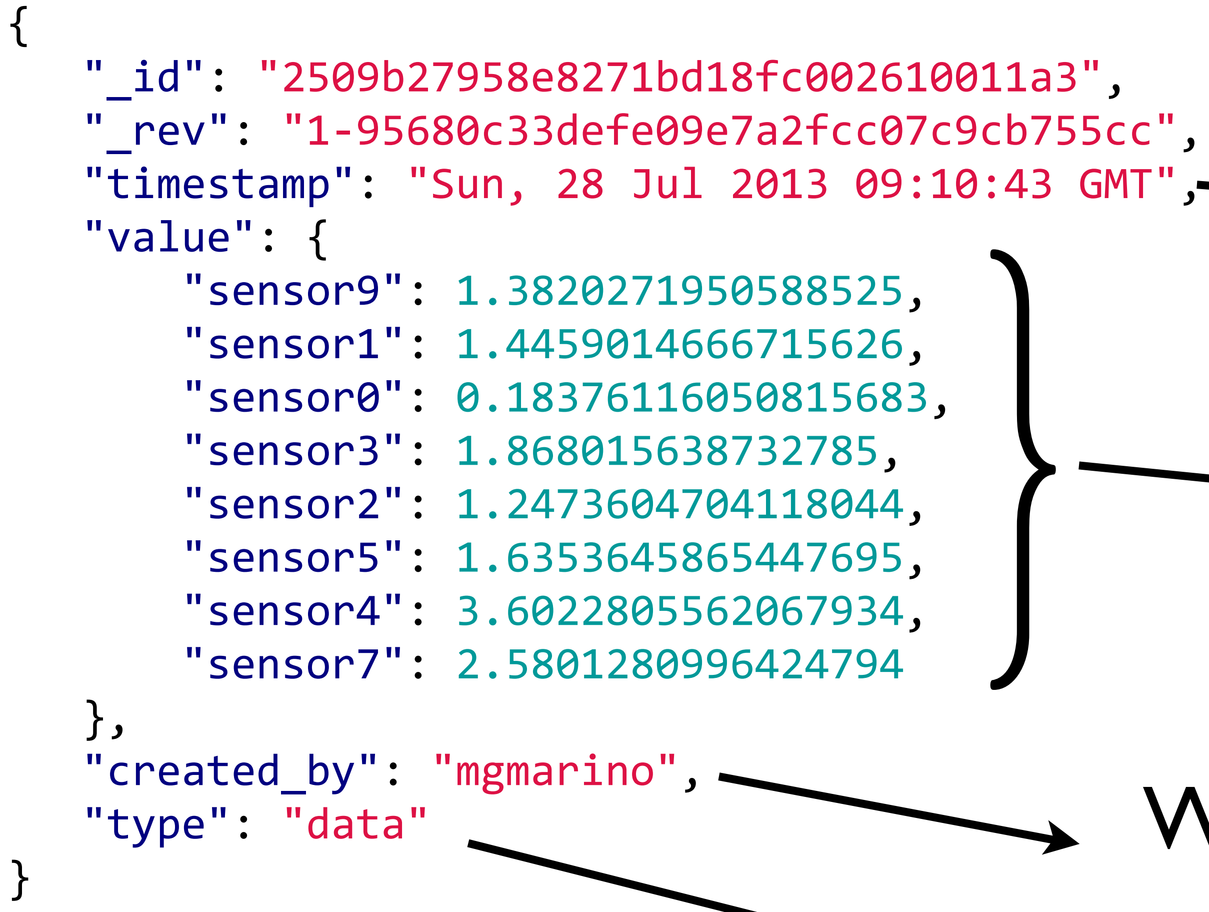
Remote monitoring + control (bi-directional replication)

Writing data, and a subsystem example

Writing to the database

Generally, only “slow” data is written to a database for a system (write frequency ~ 1/s to 1/min)

Unified “data” used across different subsystems



```
{
   "_id": "2509b27958e8271bd18fc002610011a3",
   "_rev": "1-95680c33defe09e7a2fcc07c9cb755cc",
   "timestamp": "Sun, 28 Jul 2013 09:10:43 GMT",
   "value": {
       "sensor9": 1.3820271950588525,
       "sensor1": 1.4459014666715626,
       "sensor0": 0.18376116050815683,
       "sensor3": 1.868015638732785,
       "sensor2": 1.2473604704118044,
       "sensor5": 1.6353645865447695,
       "sensor4": 3.6022805562067934,
       "sensor7": 2.5801280996424794
   },
   "created_by": "mgmarino",
   "type": "data"
}
```

Timestamp in RFC 1123 (autofilled)

Dictionary of data taken at this timestamp

Who saved it (autofilled)

Slow-control data type

Writing to the database: views

We are interested in the time behaviour of variables, two main views:

Map:

Reduce:

1

```
key: [‘varname’, YYYY, MM, DD, HH, MM, SS]
value: varvalue
```

```
_stats
```

2

```
key: [YYYY, MM, DD, HH, MM, SS, ‘varname’]
value: varvalue
```

```
none
```

Writing to the database: views

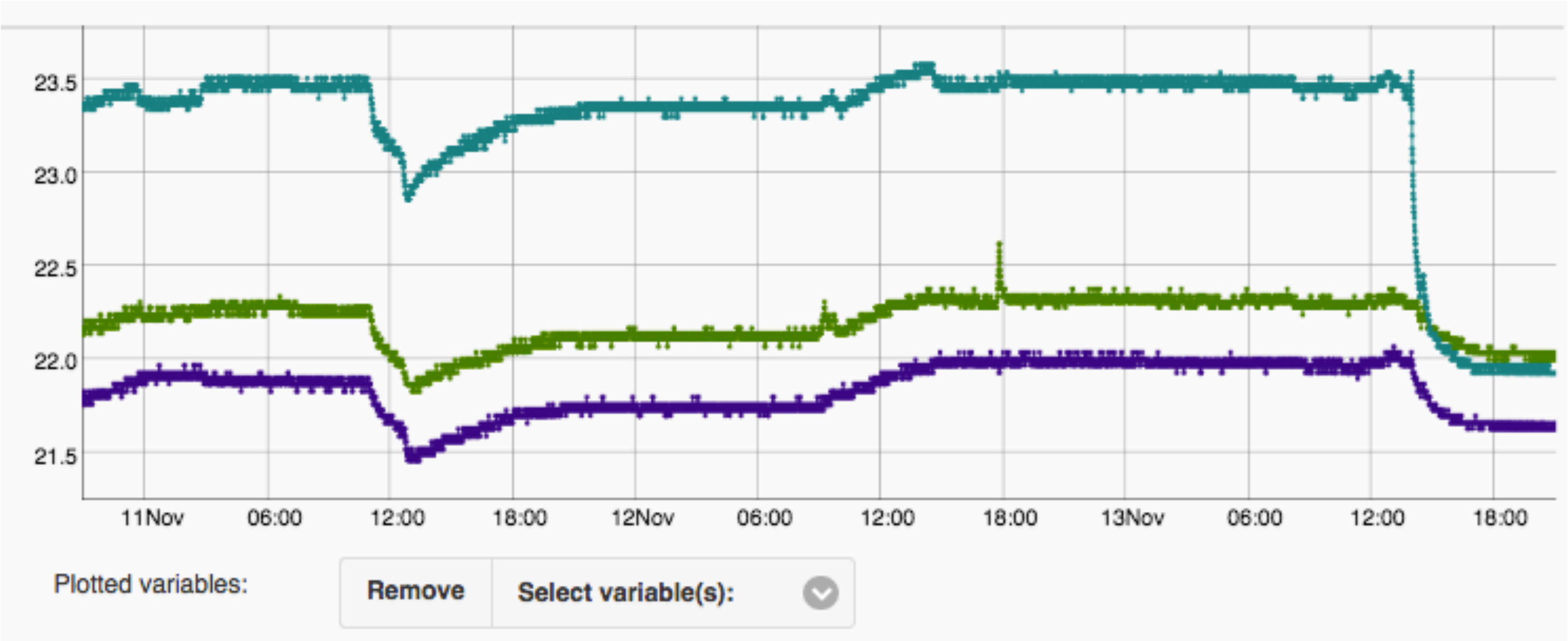
1

is used more often, especially in our web interface, allowing us to easily look at the average (or extreme values) over time (and live, via changes)

Temperatures:

seconds

`group_level=7`



`['varname', YYYY, MM, DD, HH, MM, SS]`

Writing to the database: views

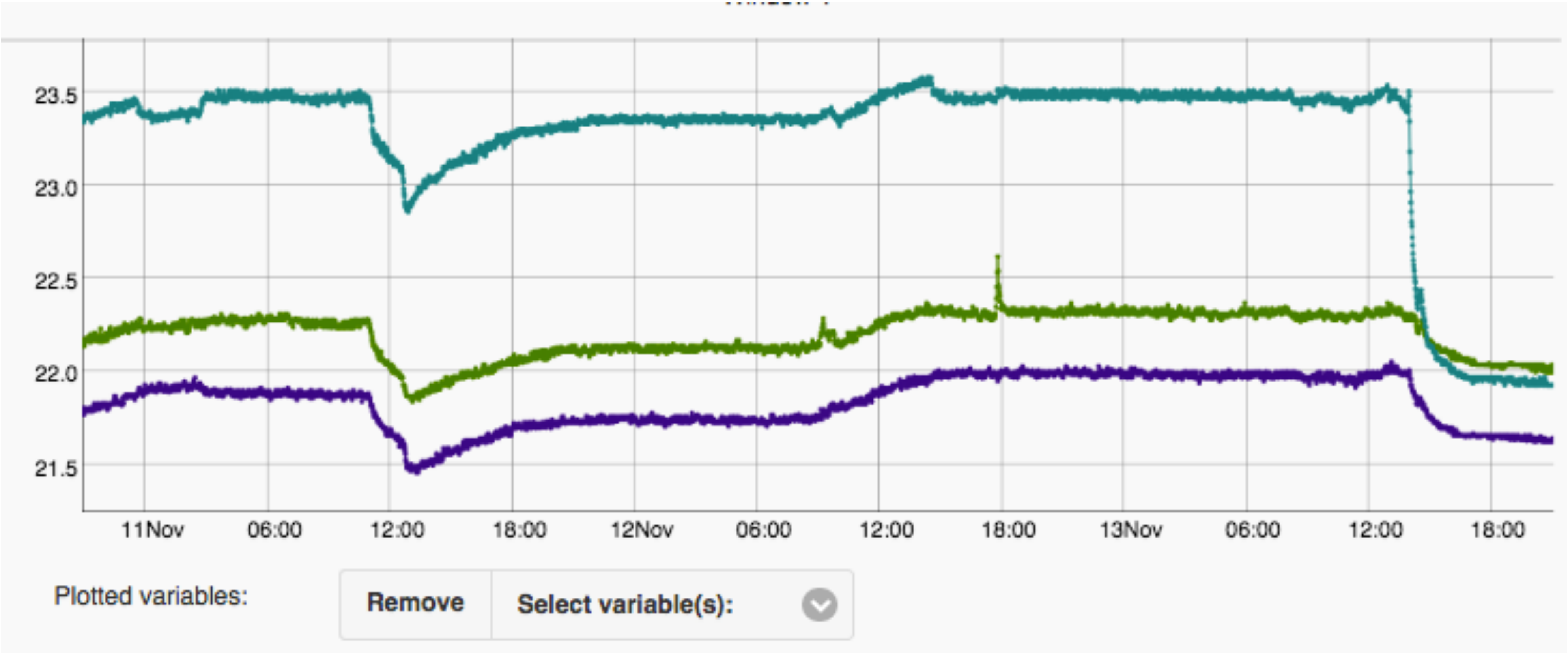
1

is used more often, especially in our web interface, allowing us to easily look at the average (or extreme values) over time (and live, via changes)

Temperatures:

minutes

`group_level=6`



`[‘varname’, YYYY, MM, DD, HH, MM]`

Writing to the database: views

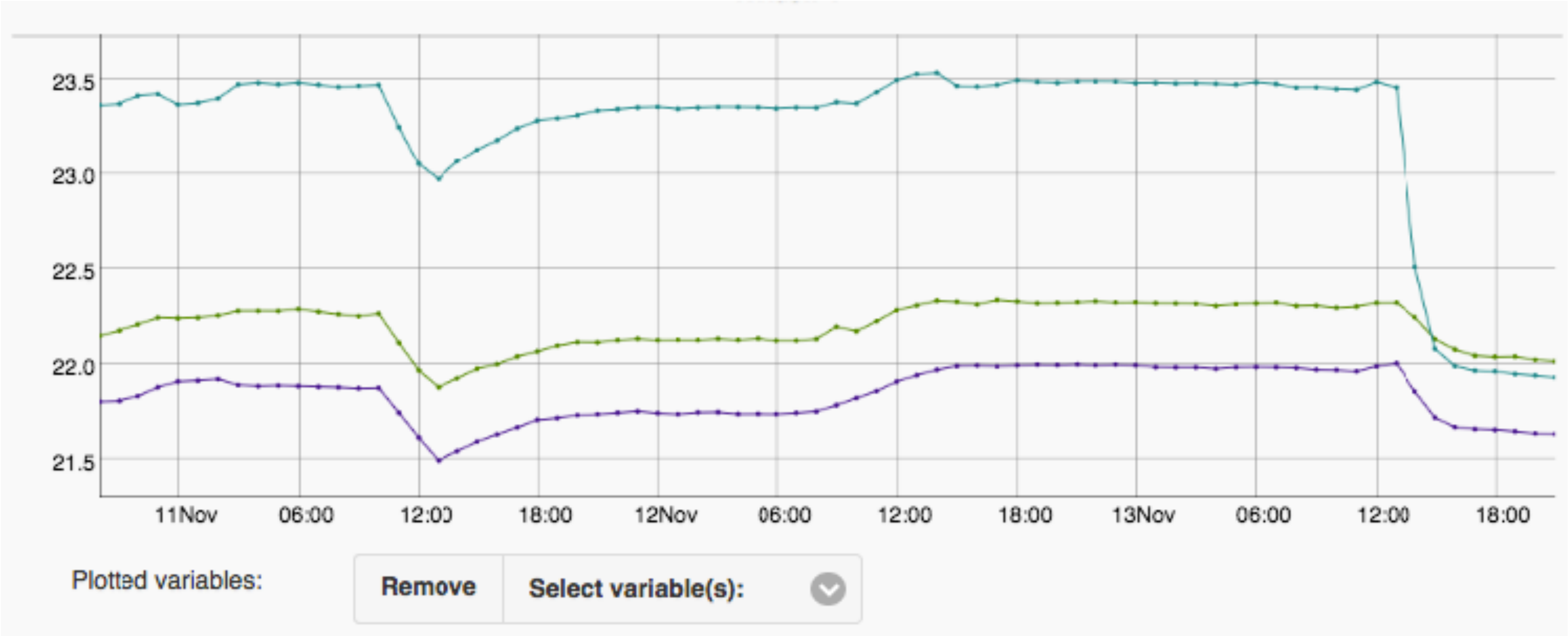
1

is used more often, especially in our web interface, allowing us to easily look at the average (or extreme values) over time (and live, via changes)

Temperatures:

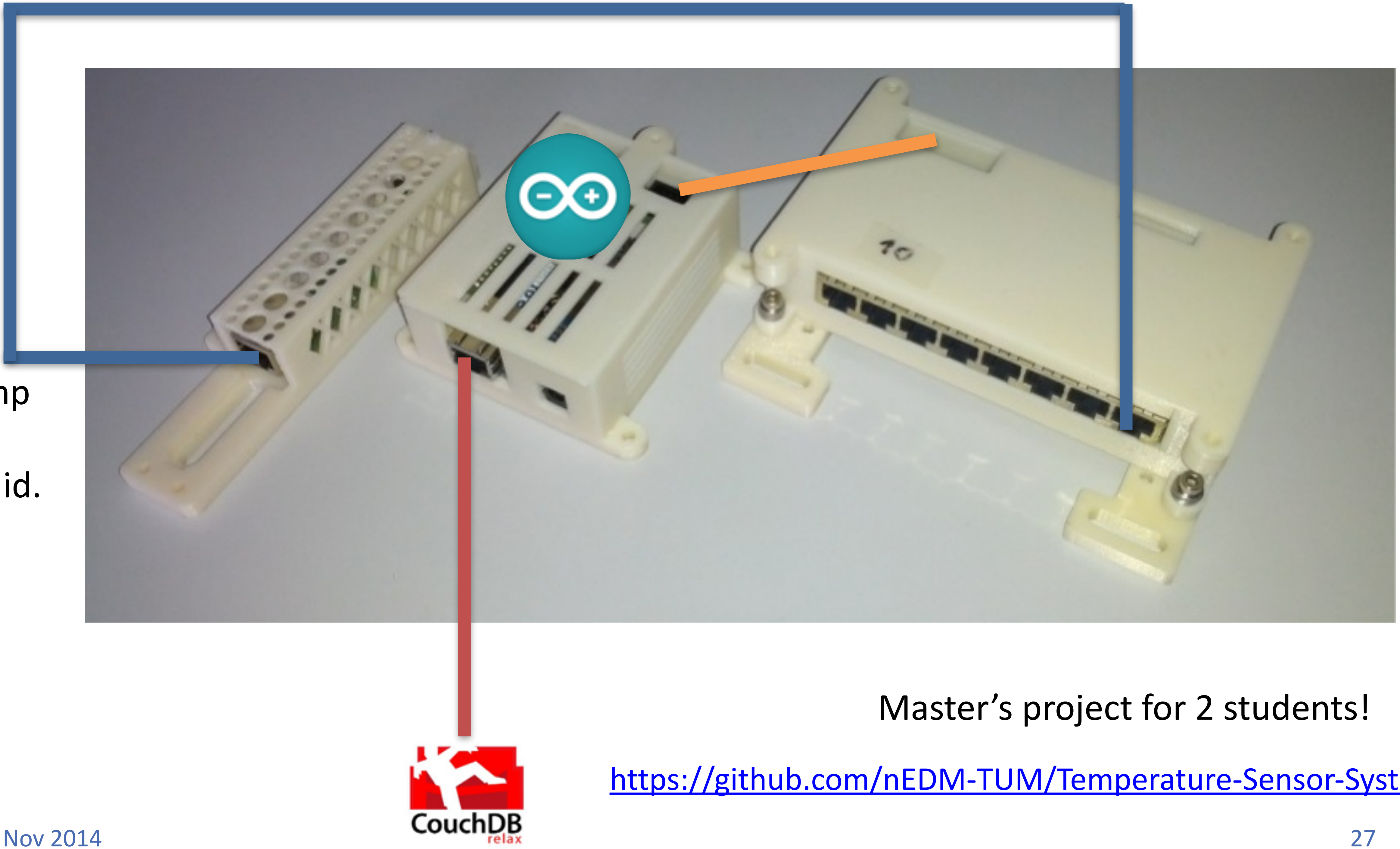
hours

`group_level=5`



`[‘varname’, YYYY, MM, DD, HH]`

Temperature subsystem



~ 45 Temp Sensors
+ 2 Humid. Sensors

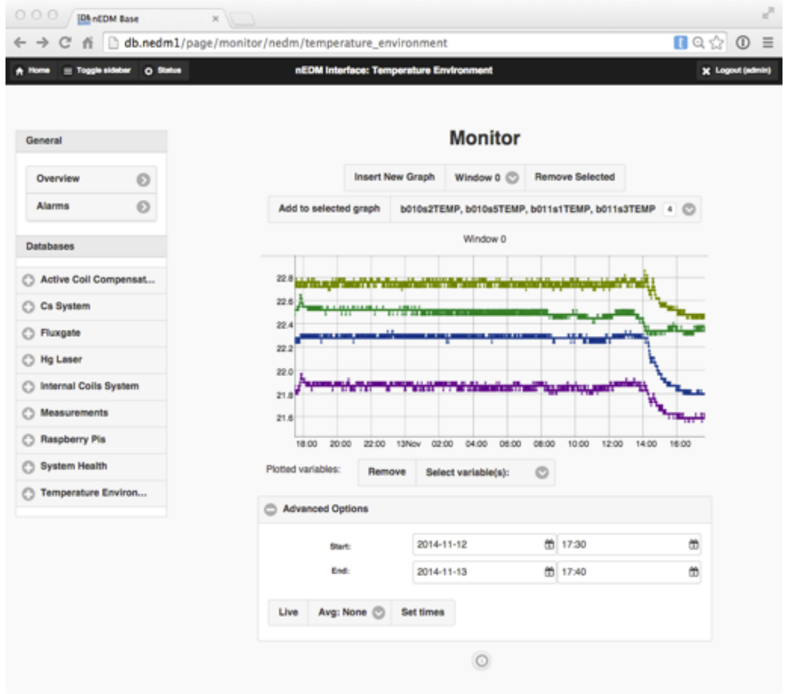
Master’s project for 2 students!

https://github.com/nEDM-TUM/Temperature-Sensor-System

Controlling a subsystem

Basic concept

CouchApp


nEDM Base

db.nedm1/page/monitor/nedm/temperature_environment

Home | Toggle sidebar | Status | nEDM Interface: Temperature Environment | Logout (admin)

General
- Overview
- Alarms

Databases
- Active Coil Compensat...
- Cs System
- Fluxgate
- Hg Laser
- Internal Coils System
- Measurements
- Raspberry Pis
- System Health
- Temperature Environ...

Monitor

Insert New Graph | Window 0 | Remove Selected

Add to selected graph | b010s2TEMP, b010s5TEMP, b011s1TEMP, b011s3TEMP | 4

Window 0

Plotted variables: | Remove | Select variable(s):

Advanced Options

Start: 2014-11-12 17:30

End: 2014-11-13 17:40

Live | Avg: None | Set times

Hardware devices

ORCA

NATIONAL INSTRUMENTS LabVIEW

CASCADE

python™

Control

Control via changes feed

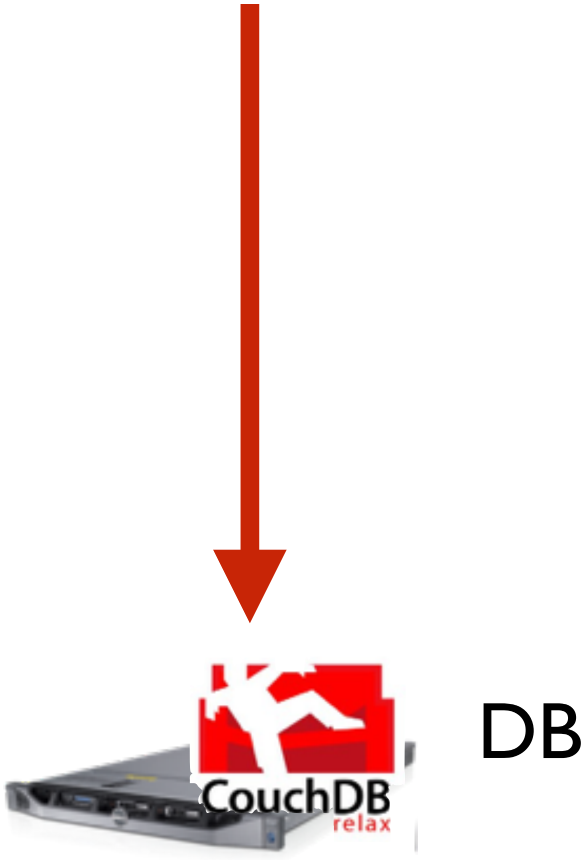
CouchDB

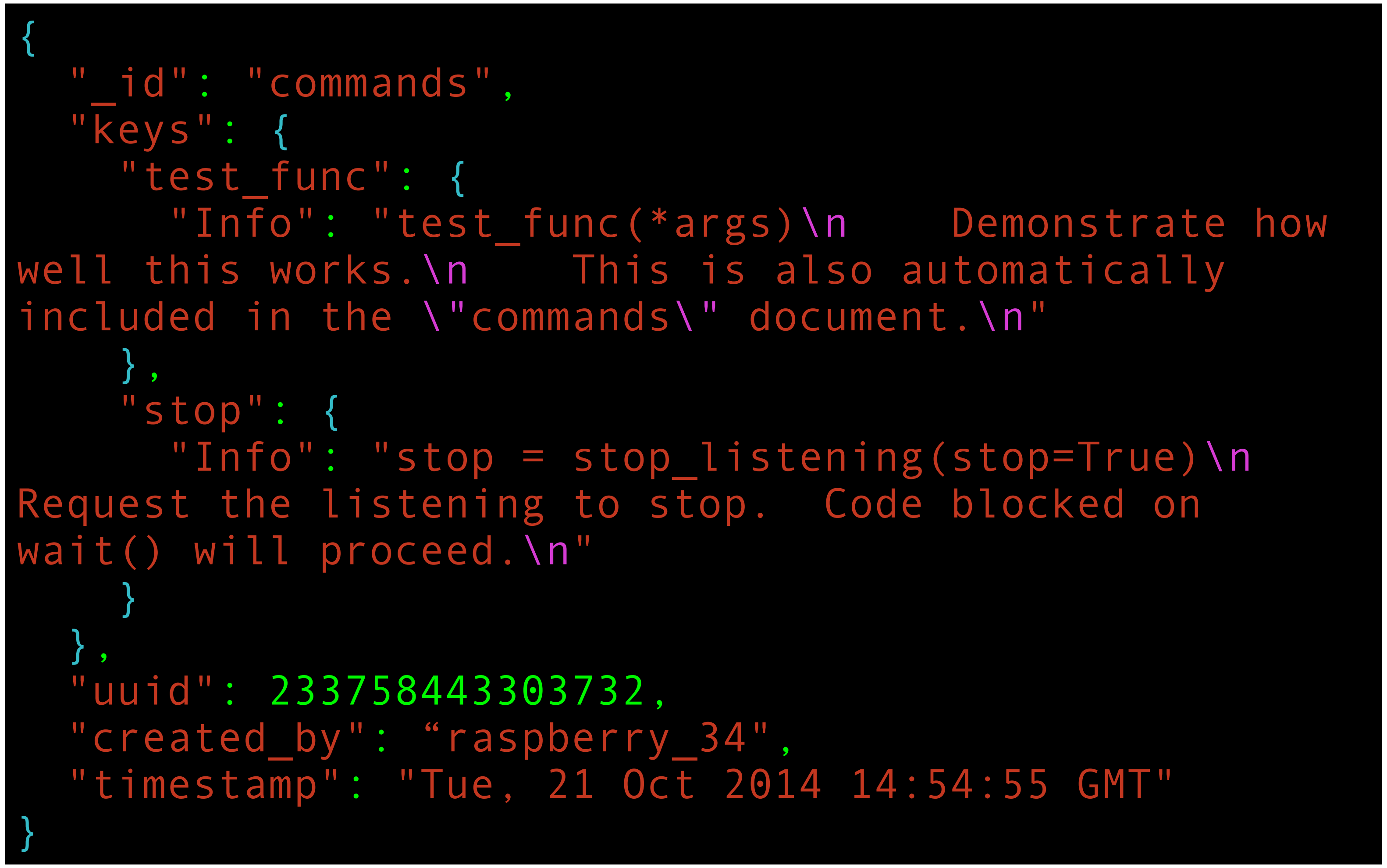
CouchDB relax

Overview

1

Subsystem saves a document with the list of available commands:

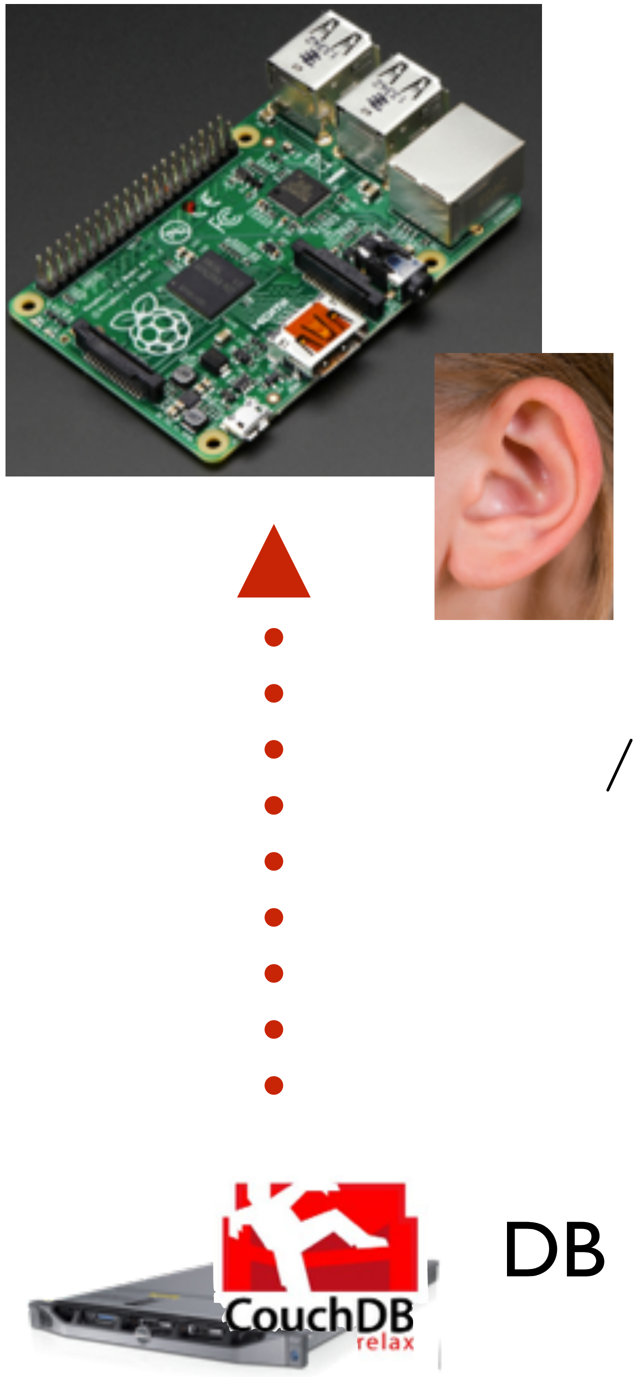




```
{
  "_id": "commands",
  "keys": {
    "test_func": {
      "Info": "test_func(*args)\n    Demonstrate how
well this works.\n    This is also automatically
included in the \"commands\" document.\n"
    },
    "stop": {
      "Info": "stop = stop_listening(stop=True)\n
Request the listening to stop.  Code blocked on
wait() will proceed.\n"
    }
  },
  "uuid": 233758443303732,
  "created_by": “raspberry_34",
  "timestamp": "Tue, 21 Oct 2014 14:54:55 GMT"
}
```

Overview

2



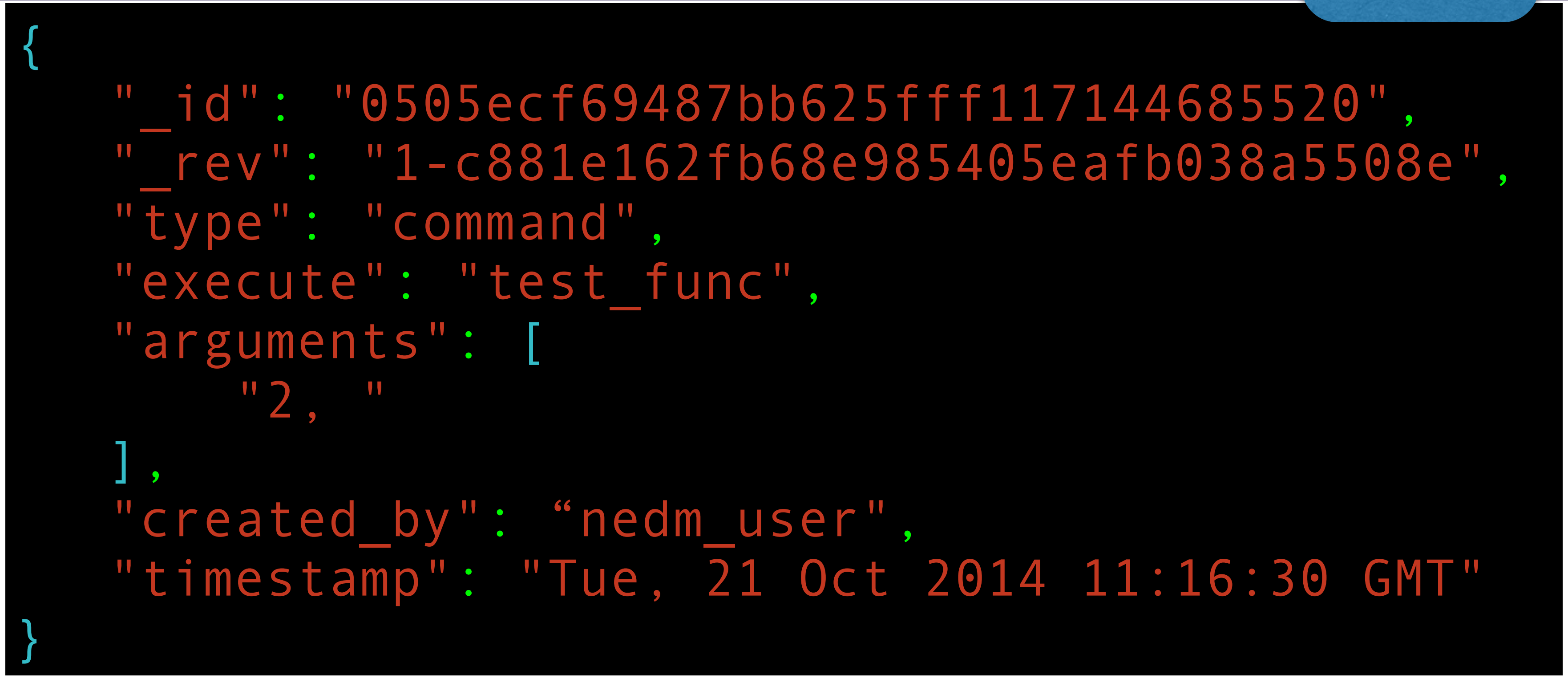
Subsystem waits for command document, listens to changes feed

```
/db/_changes?feed=continuous&heartbeat=5000&
filter=execute_commands/execute_commands
```

filter on “command” documents

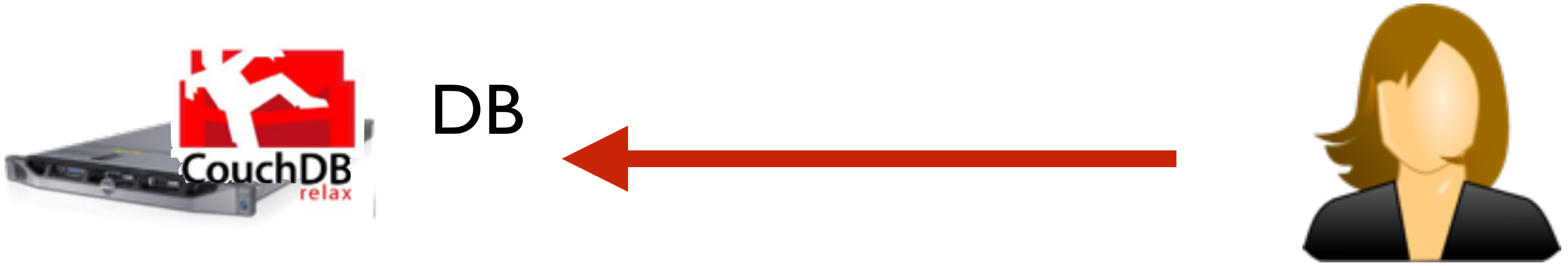
Overview

3



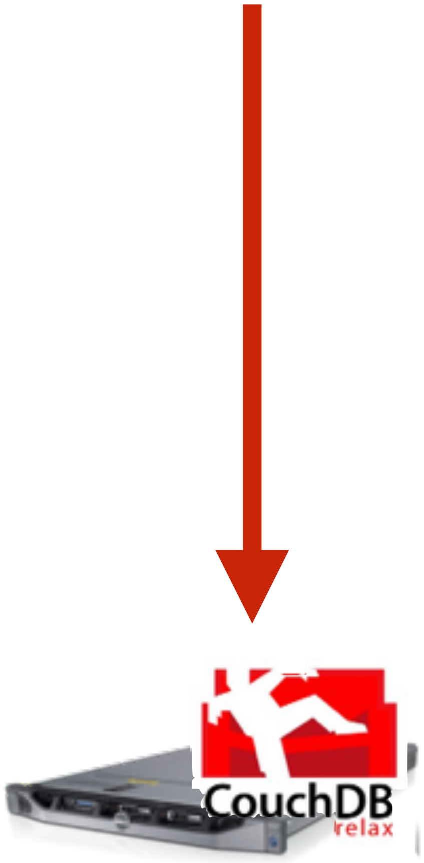
```
{
   "_id": "0505ecf69487bb625fff117144685520",
   "_rev": "1-c881e162fb68e985405eafb038a5508e",
   "type": "command",
   "execute": "test_func",
   "arguments": [
       "2, "
   ],
   "created_by": “nedm_user",
   "timestamp": "Tue, 21 Oct 2014 11:16:30 GMT"
}
```

A command document is saved by a user, either from web interface or from another program.

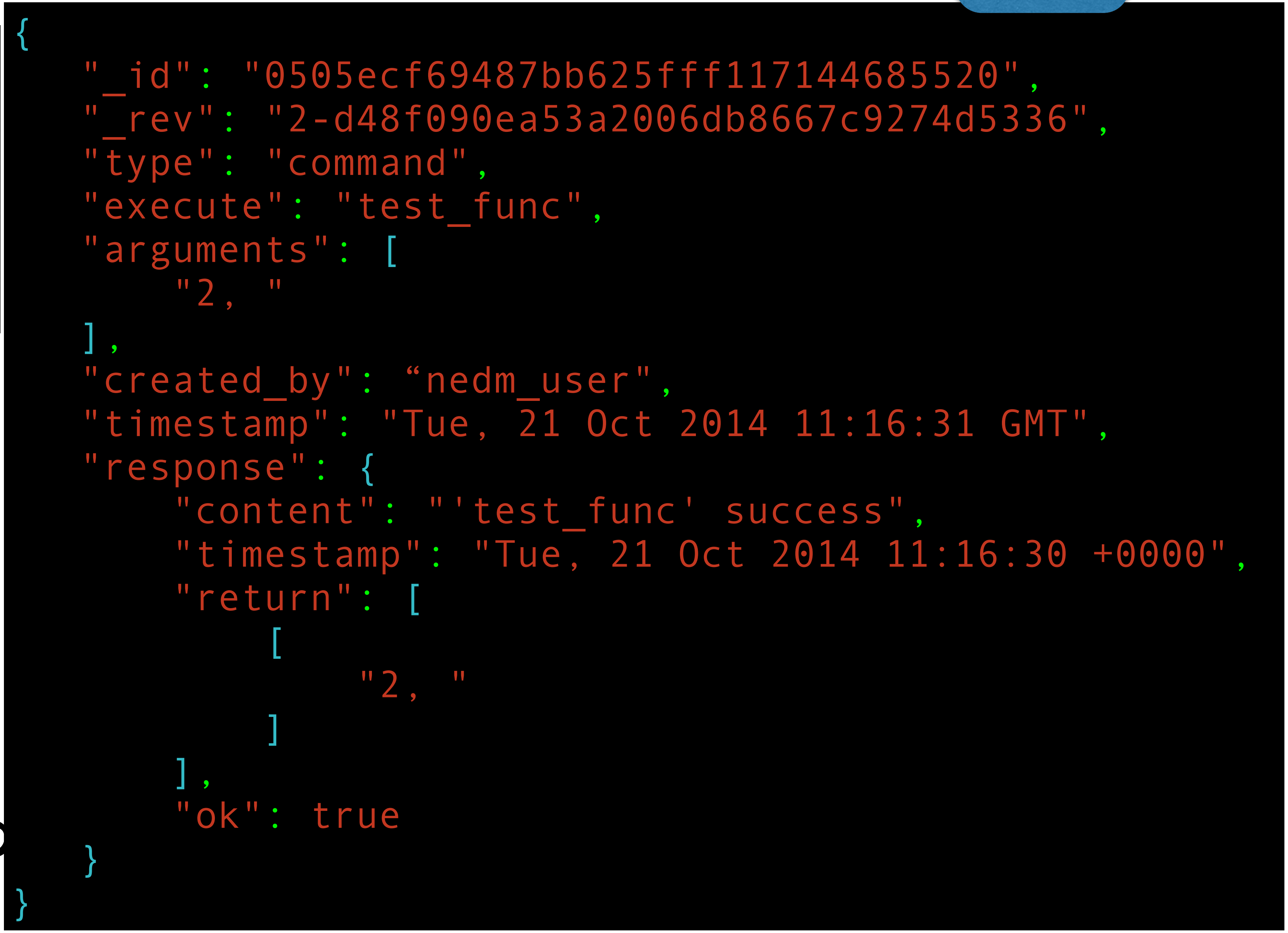


Overview

4



D

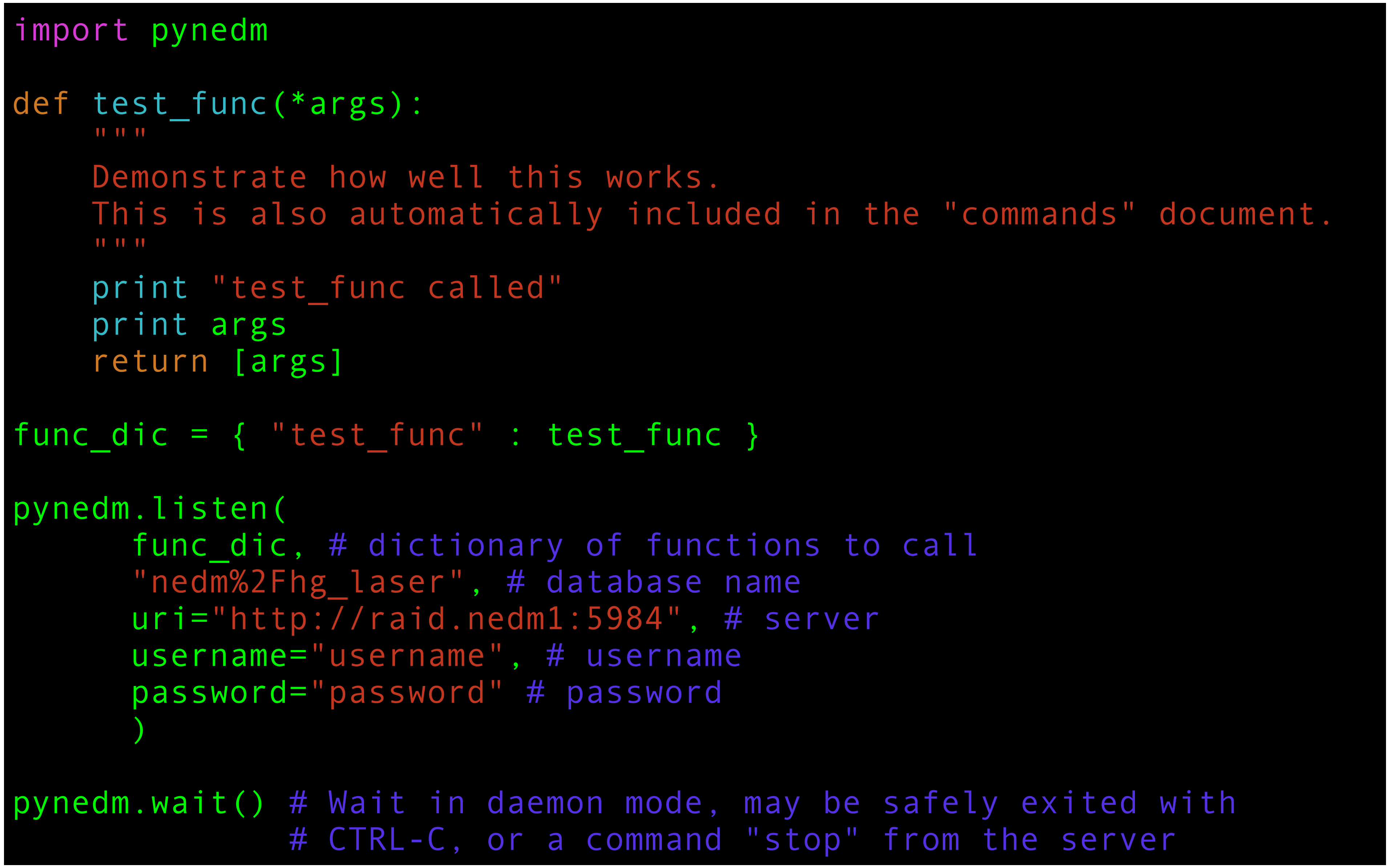


```
{
   "_id": "0505ecf69487bb625fff117144685520",
   "_rev": "2-d48f090ea53a2006db8667c9274d5336",
   "type": "command",
   "execute": "test_func",
   "arguments": [
       "2, "
   ],
   "created_by": “nedm_user",
   "timestamp": "Tue, 21 Oct 2014 11:16:31 GMT",
   "response": {
       "content": "'test_func' success",
       "timestamp": "Tue, 21 Oct 2014 11:16:30 +0000",
       "return": [
           [
               "2, "
           ]
       ],
       "ok": true
   }
}
```

Caveats:

- This is not a “real-time” command system!
- The “glue” for each subsystem must be written

Most of the time, we can write this in Python, and we have a module that handles this…



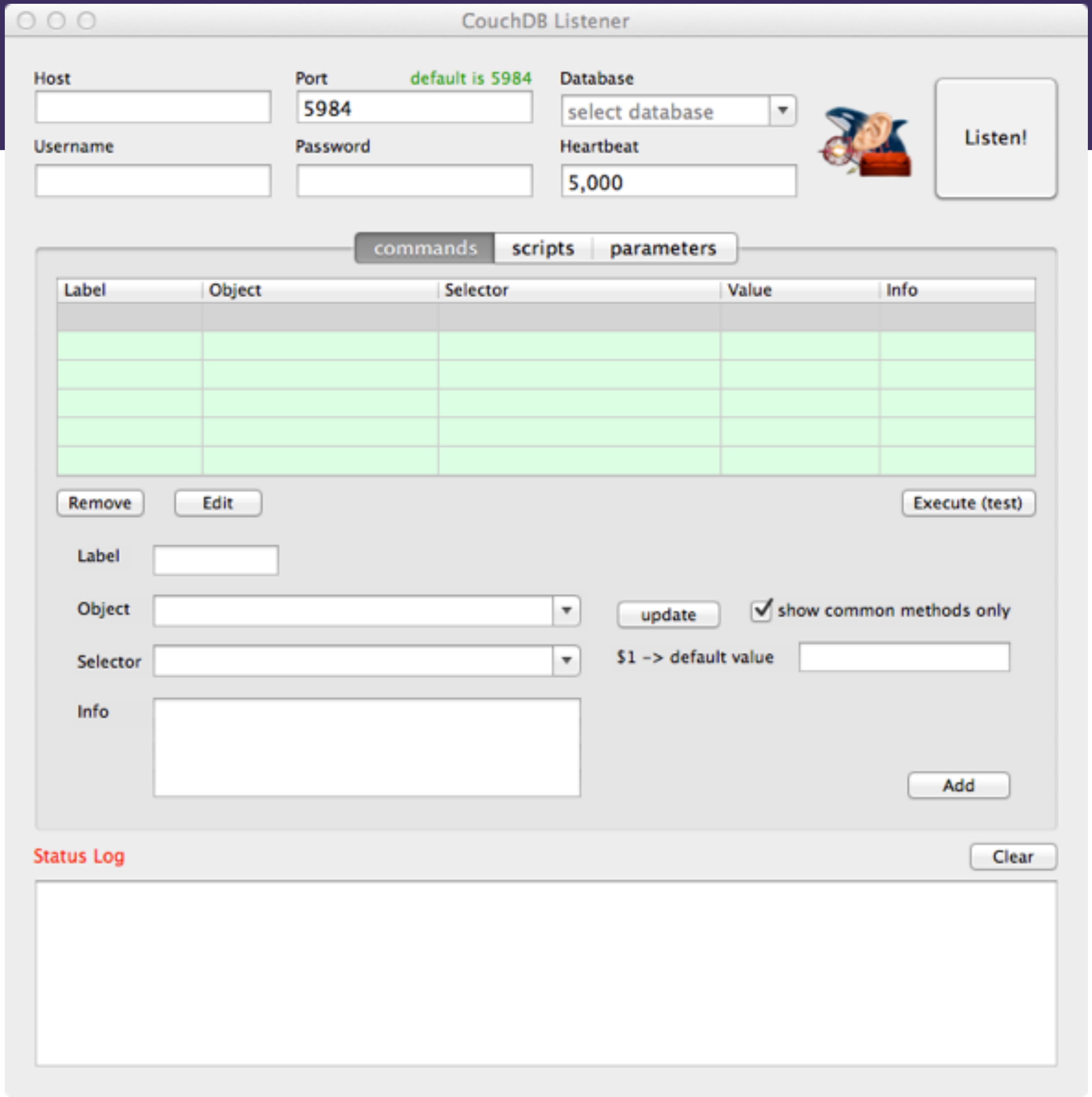
```
import pynedm

def test_func(*args):
    """
    Demonstrate how well this works.
    This is also automatically included in the "commands" document.
    """
    print "test_func called"
    print args
    return [args]

func_dic = { "test_func" : test_func }

pynedm.listen(
      func_dic, # dictionary of functions to call
      "nedm%2Fhg_laser", # database name
      uri="http://raid.nedm1:5984", # server
      username="username", # username
      password="password" # password
      )

pynedm.wait() # Wait in daemon mode, may be safely exited with
              # CTRL-C, or a command "stop" from the server
```

pynedm: https://github.com/nEDM-TUM/Python-Slow-Control

Uses: https://github.com/cloudant-labs/cloudant-python !

… but we also have something for Objective-C for ORCA (an open-source, Mac OS X-based data acquisition software)

ORCA
Object-oriented Real-time Control and Acquisition
University of North Carolina
Physics and Astronomy Department
Chapel Hill
Department of Energy Grant
DE-FG02-97ER41020
Made with Cocoa



Host:

Port: 5984 (default is 5984)

Database: select database

Username:

Password:

Heartbeat: 5,000

Label:

Object:

Selector:

☑ show common methods only

$1 -> default value:

Info:

http://orca.physics.unc.edu/~markhowe/Database_Support/CouchDB_Listener.html

… and also for straight C (when we *have* to)

Pillowtalk

Original https://github.com/jubos/pillowtalk

Forked https://github.com/mgmarino/pillowtalk
(with changes feed notifications, Windows + *X support)

(Closed source, but can load C libraries)

Have implemented, tested, but until now have always been able to use Python in favor of the pure C “glue”

A few more points

The command system doesn’t need to “export” the entire functionality of the subsystem. Generally, only a small subset of commands are necessary

ToDo: Locking mechanisms to ensure only “one user” is controlling system. Designed, not yet implemented

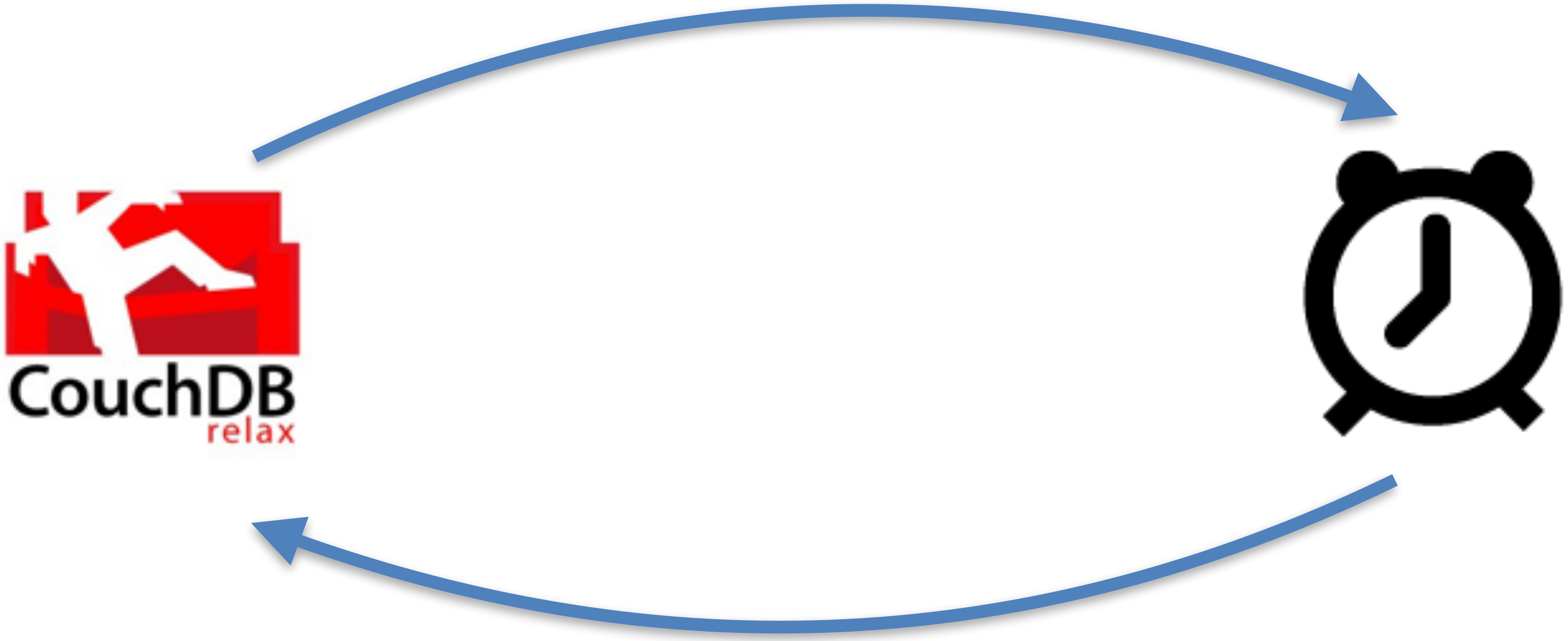
Some more “goodies”

Alarms/Notifications

All good monitoring/slow-control systems must provide notifications if certain events occur:

i.e. a value exceeds a limit, a valve opens, etc.

Our best solution: OS daemon



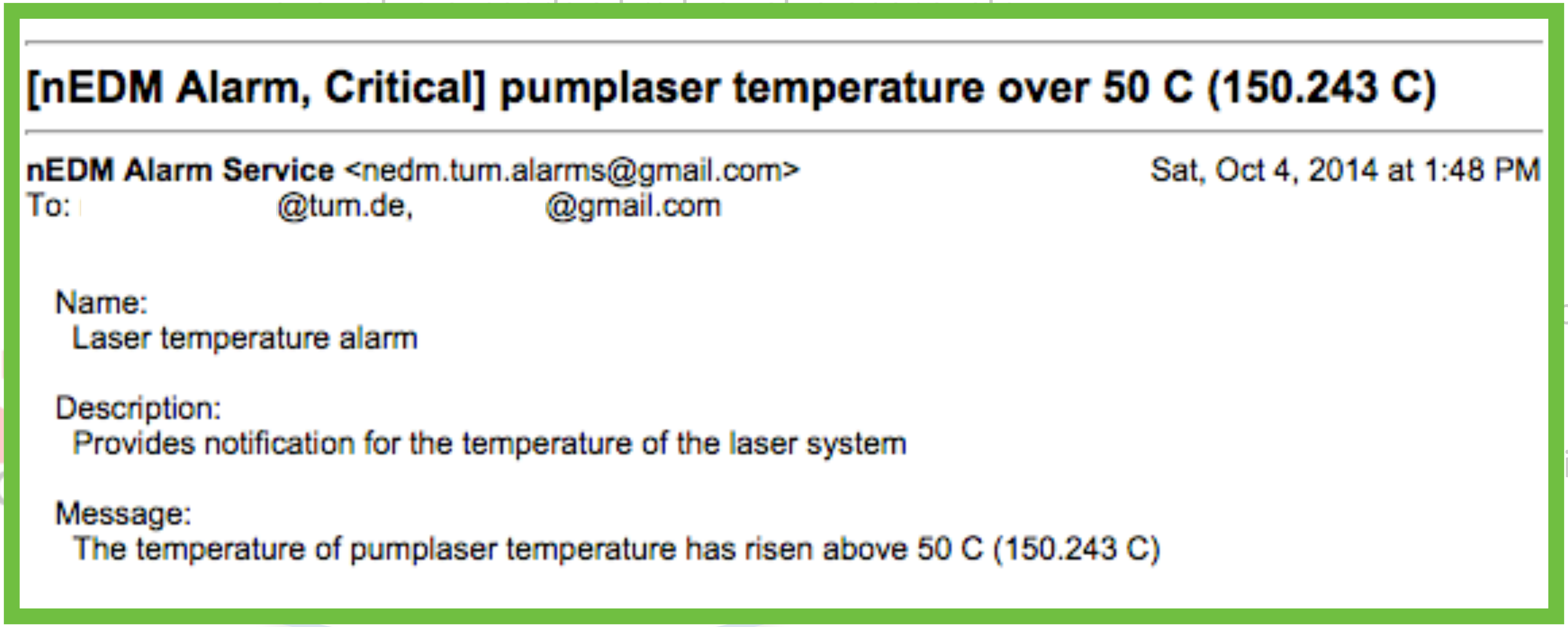
Auto started/configured by CouchDB

Polls to determine condition exceptions

https://github.com/nEDM-TUM/Slow-Control-Misc/blob/master/couchdb_alarm_daemon.py

Alarms/Notifications

All good monitoring/slow-control systems must provide notifications if certain events occur:



[nEDM Alarm, Critical] pumplaser temperature over 50 C (150.243 C)

nEDM Alarm Service <nedm.tum.alarms@gmail.com> Sat, Oct 4, 2014 at 1:48 PM
To: [redacted]@tum.de, [redacted]@gmail.com

Name:
Laser temperature alarm

Description:
Provides notification for the temperature of the laser system

Message:
The temperature of pumplaser temperature has risen above 50 C (150.243 C)

https://github.com/nEDM-TUM/Slow-Control-Misc/blob/master/couchdb_alarm_daemon.py

Raspberries

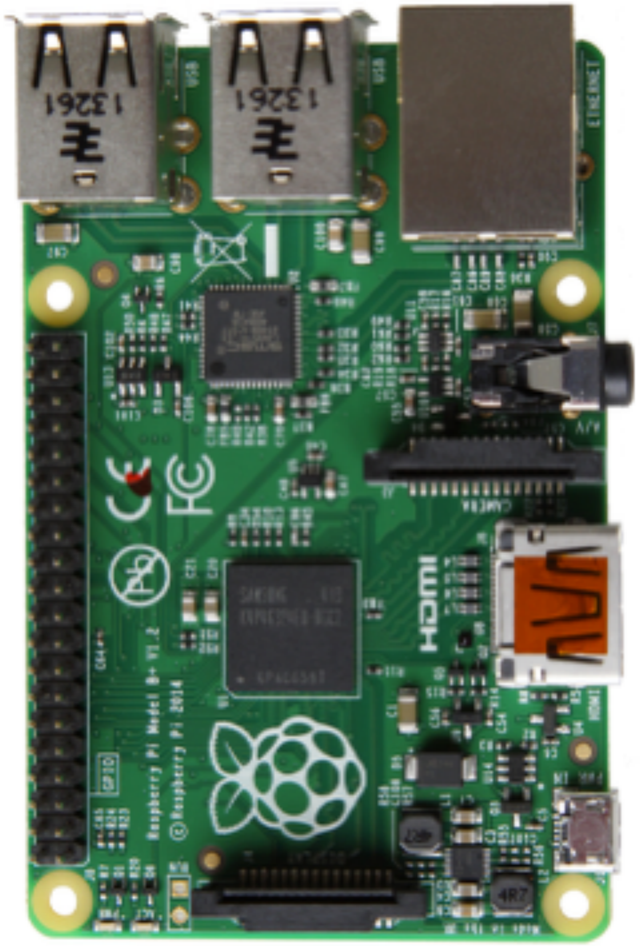
(Almost all) devices live on our local experiment network and many support SCPI:

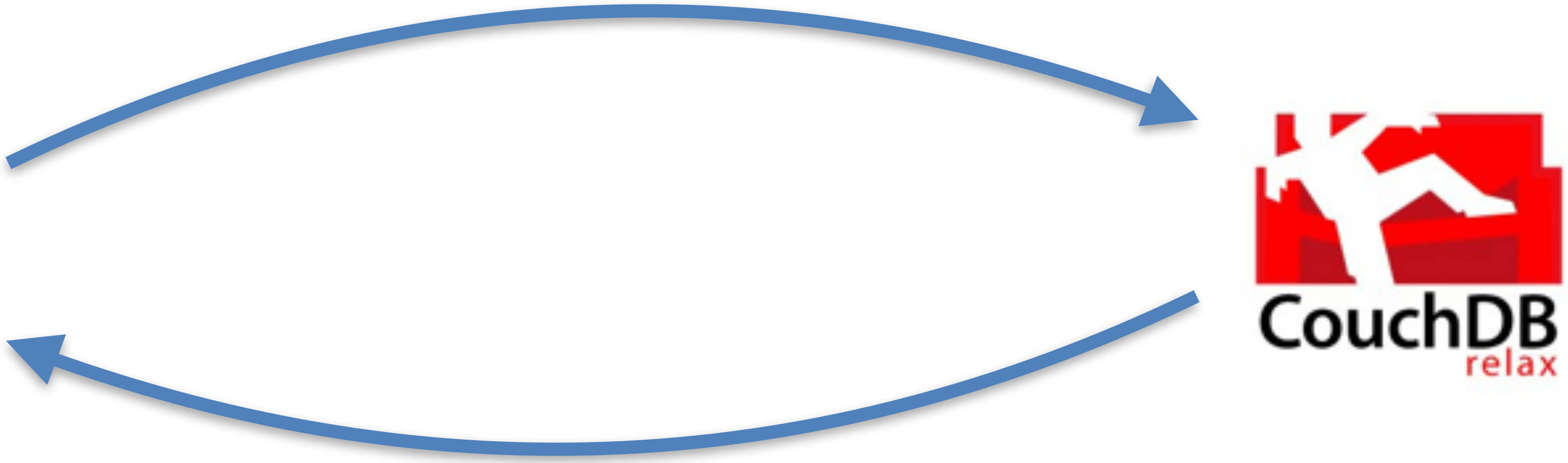
e.g. “*IDN?”, “*CAL”, etc.

Almost all of these now run over Ethernet (instead of GPIB, RS-232, USB, etc.)

Desktop = overkill

Raspberries



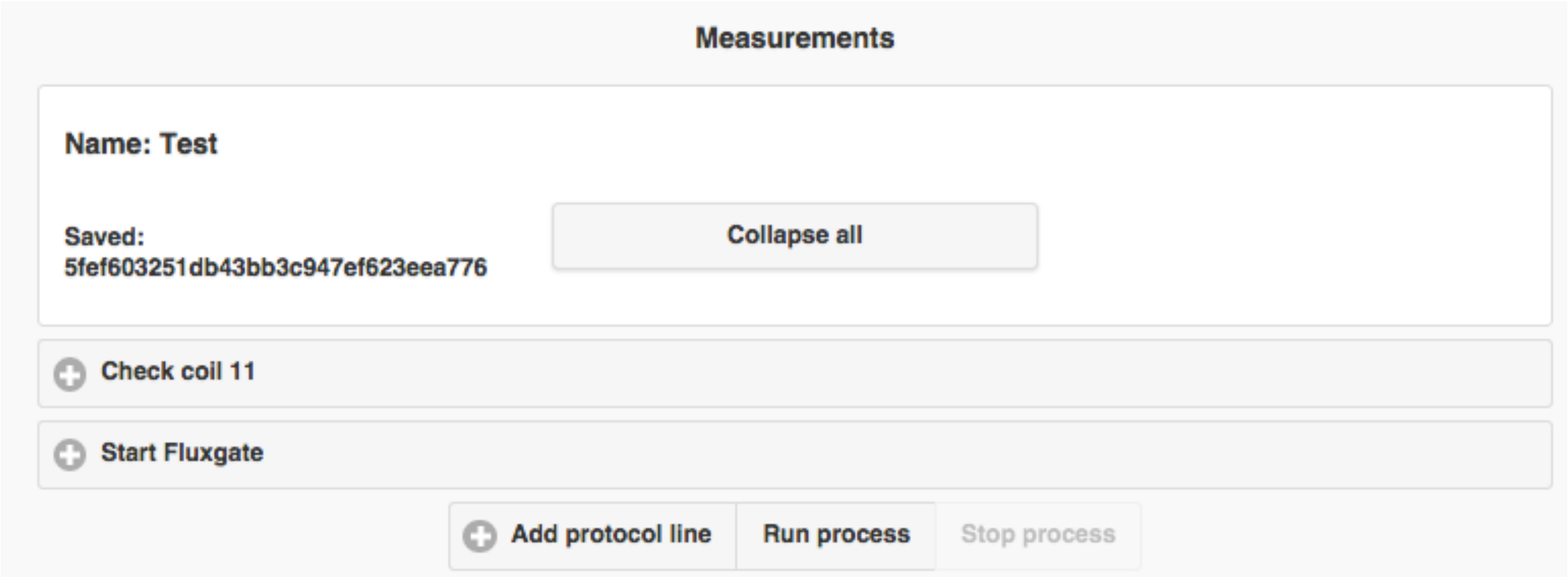


1. On boot: request code from CouchDB (identified by MAC)
2. Run “readout” code
3. Listen for changes (restart “readout” code with changes)

Runs a python daemon (HimbeereCouch):

https://github.com/nEDM-TUM/HimbeereCouch

Putting it all together…



Measurements

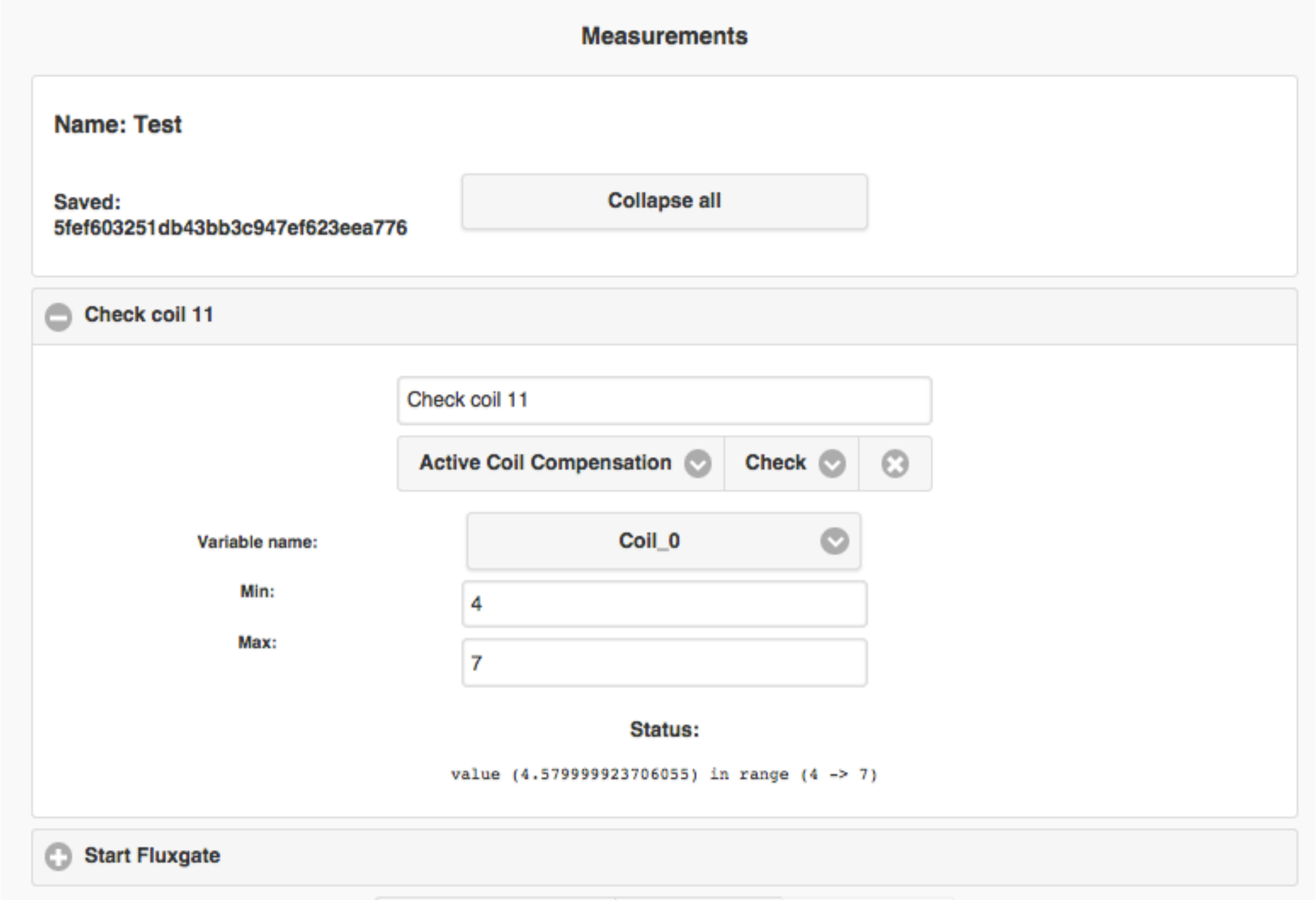
Name: Test

Saved: 5fef603251db43bb3c947ef623eea776

An excerpt from our HTML interface:

https://github.com/nEDM-TUM/nEDM-Interface

Putting it all together…



Measurements

Name: Test

Saved: 5fef603251db43bb3c947ef623eea776

Check coil 11

Check coil 11

Active Coil Compensation

Check

Variable name: Coil_0

Min: 4

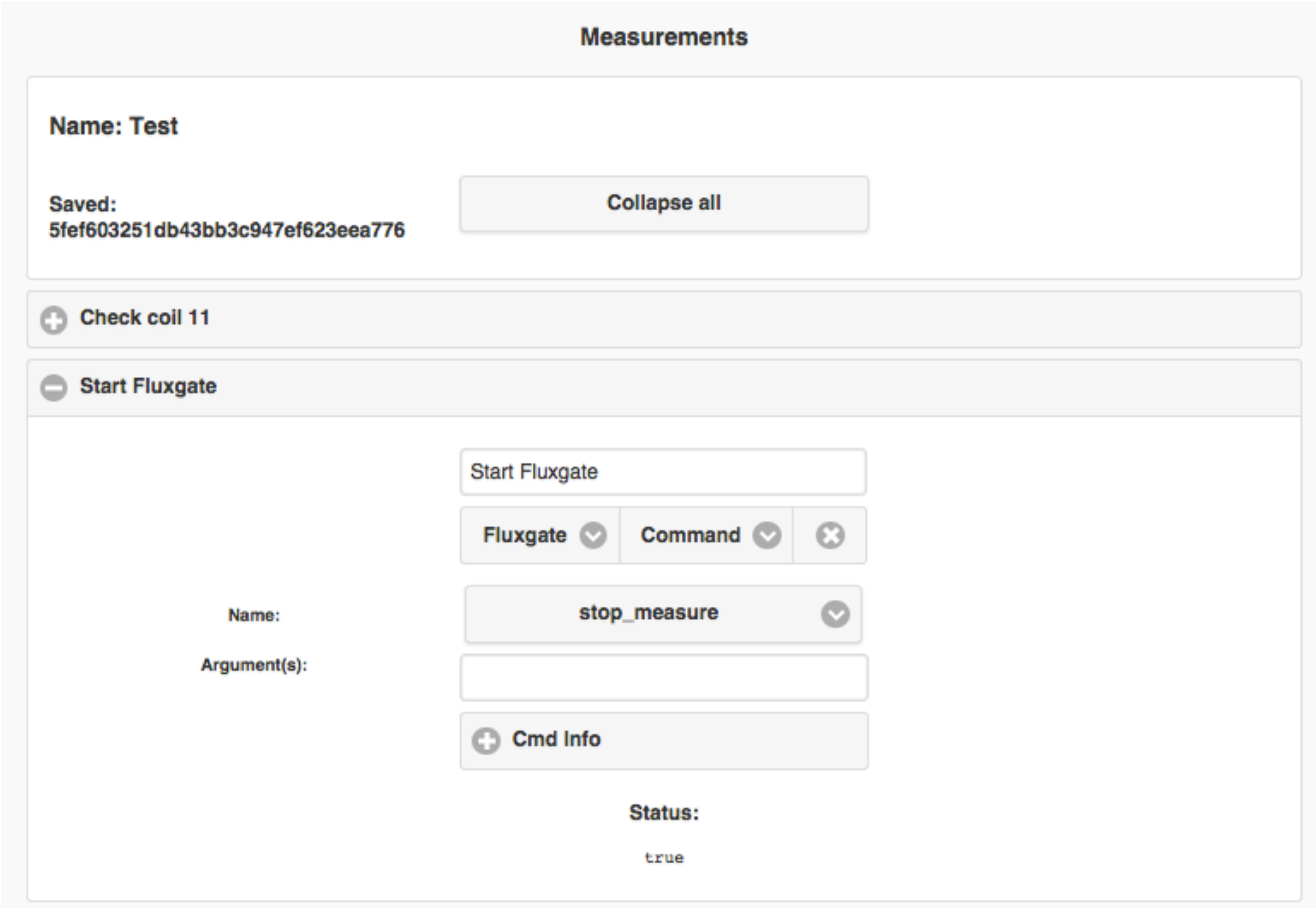
Max: 7

Status:

```
value (4.579999923706055) in range (4 -> 7)
```

Start Fluxgate

Putting it all together…



Measurements

Name: Test

Saved:
5fef603251db43bb3c947ef623eea776

Collapse all

⊕ Check coil 11

⊖ Start Fluxgate

Start Fluxgate

Fluxgate ⌄ | Command ⌄ | ⊗

Name: stop_measure ⌄

Argument(s):

⊕ Cmd Info

Status:

`true`

A (shrunk-down) read-only example

https://nedmtum.cloudant.com/nedm_head/_design/nedm_head/_rewrite/

(Continuous) replication of a subset of our systems, with some live examples

Kindly hosted by:

Cloudant

UN + Password: apachecon2014

Summary

- The nEDM experiment at TUM is trying to help explain the matter-anti-matter asymmetry in the universe.

- CouchDB is an essential piece of the data acquisition system used by the nEDM experiment. It allows the integration, control and readout of many distinct sub-systems.

Credits

nEDM-TUM collaboration

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DFG Deutsche Forschungsgemeinschaft

This work supported partially by SPP 1491 funds

Thanks for your attention!

Questions?