Karlsruher Institut für Technologie

UNSAM
UNIVERSIDAD NACIONAL DE SAN MARTÍN

PIERRE AUGER OBSERVATORY

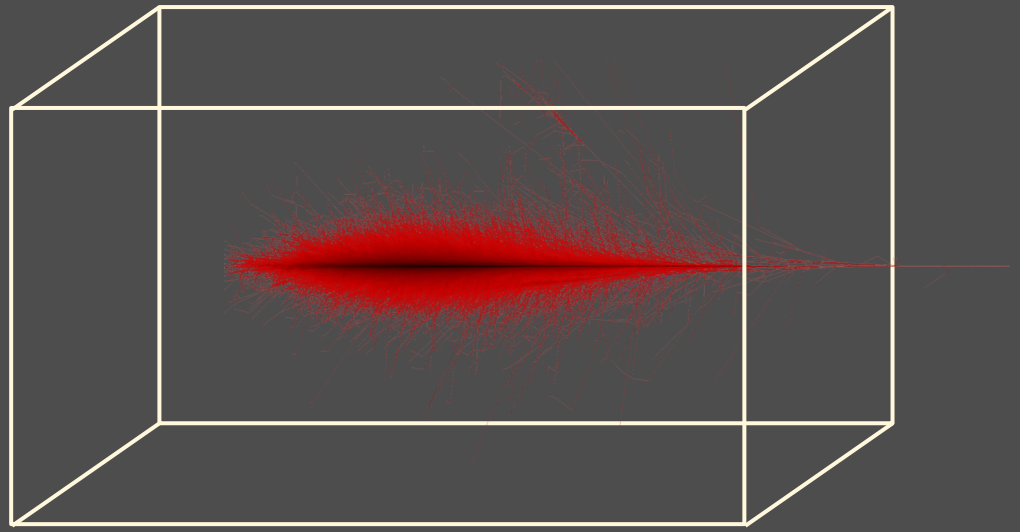
News on Universality-v2

Max Stadelmaier, supervised by

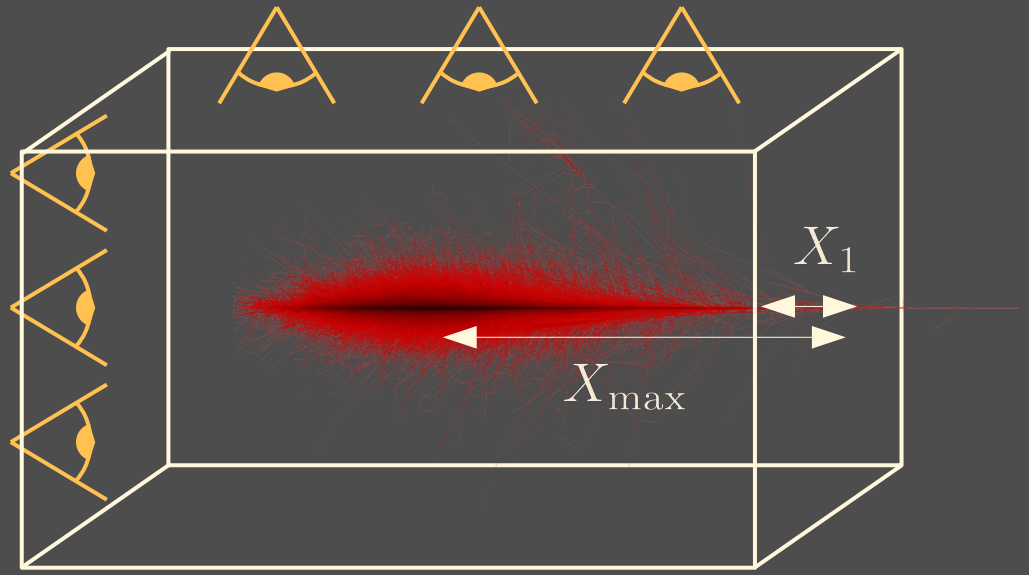
Ralph Engel & Markus Roth

Federico Sanchez

in a perfect world …

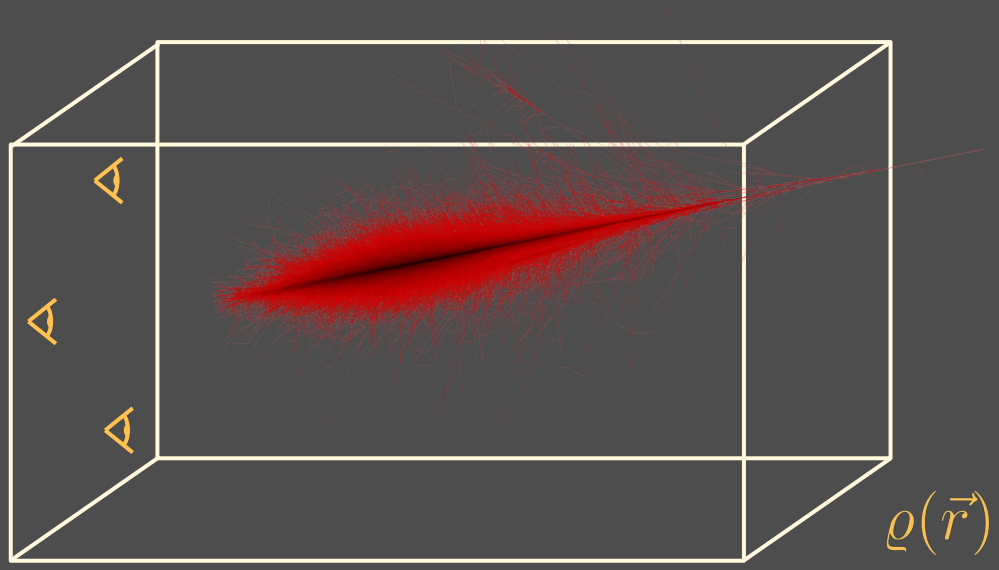


in a perfect world …



$$\varrho(\vec{r}) = const. \Rightarrow \sigma \simeq \frac{\varrho}{\langle X_1 \rangle}$$

… sadly



$$\varrho(\vec{r}) = f(z,t)$$

- The atmosphere is not homogeneous, and
- we can not detect all particles or all light emitted by an air shower.

The solution: Universality

- Universality solves this issues by taking use of the fact that the development of air showers is very similar (*universal*), given only a few input parameters:

$$E,\ \vec{r},\ R_\mu,\ X_{\max}$$

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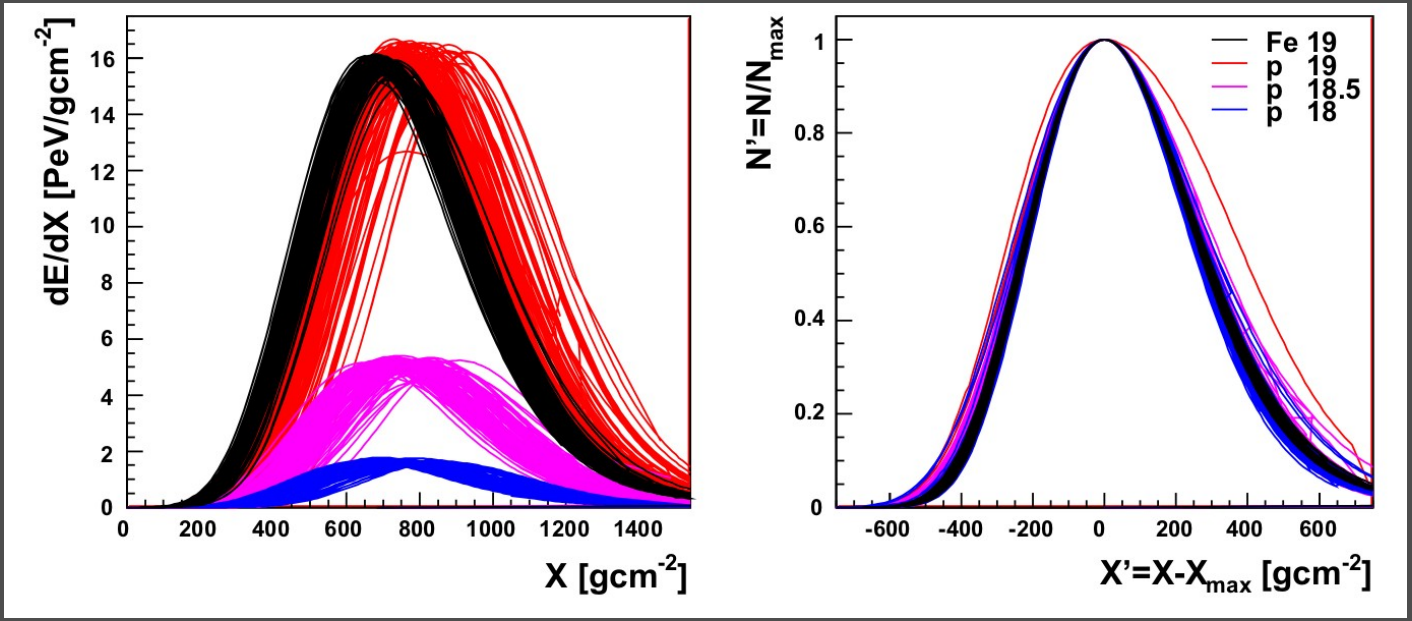
- Universality solves this issues by taking use of the fact that the development of air showers is very similar (*universal*), given only a few input parameters:

$$E,\ \vec{r},\ R_\mu,\ X_{\max}$$

primary mass dependent!

In detail:

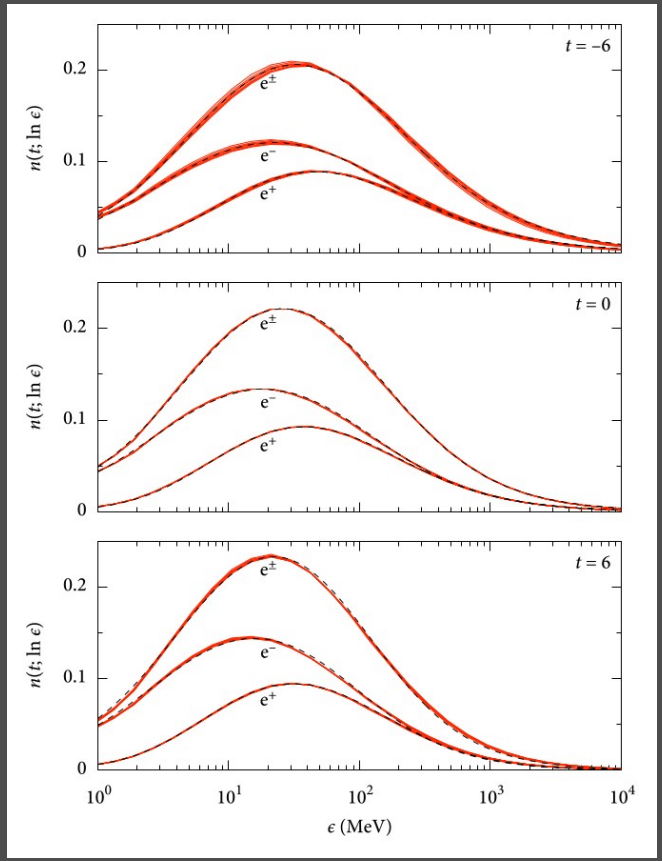
- Shape (energy deposit per depth) is universal w.r.t. $DX := X - X_{\max}$



[S. Andringa, R. Conceição, M. Pimenta, 2010]

In detail:

- Energy spectrum of most particles is universal w.r.t. $DX := X - X_{\max}$



[S. Lafebre, R. Engel, H. Falcke, J. Hörandel T. Huege, J. Kuijpers, R. Ulrich, 2009]

In detail:

- The signal can be parametrized using a (modified) Gaisser-Hillas function.

$$S(\vec{r}) = \sum_{i=1}^{4} S^i_{\mathrm{ref}}(r) f^i_{\mathrm{mod}}(\psi, r) f^i_{R_\mu} \left(\frac{E}{E_{\mathrm{ref}}}\right)^{\gamma} \left(\frac{DX - DX_0}{DX_{\mathrm{ref}} - DX_0}\right)^{\frac{DX_{\max} - DX_0}{\lambda}} \mathrm{e}^{-\frac{DX - DX_{\mathrm{ref}}}{\lambda}}$$

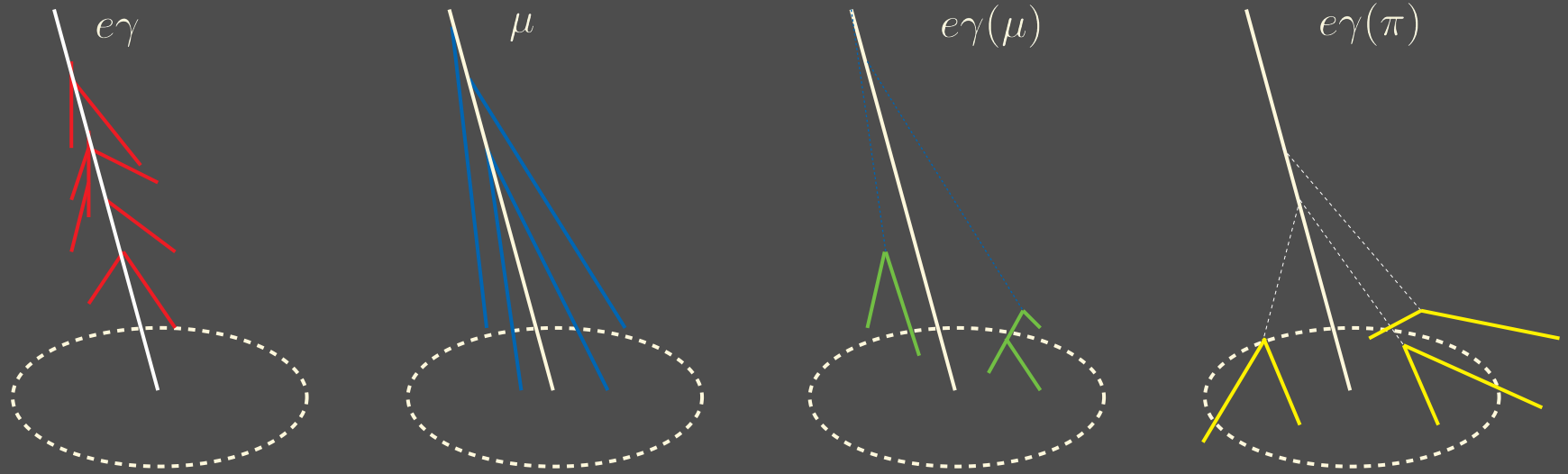
[M. Ave, R. Engel, M. Roth, A. Schulz, 2016]

- Also the time-dependent signal structure can be parametrized, using a log-normal function.

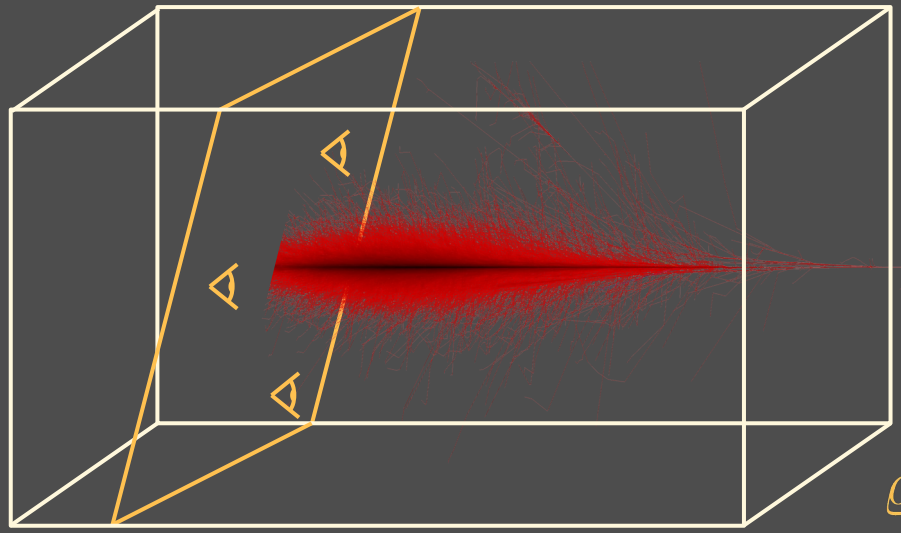
[M. Ave, M. Roth, A. Schulz, 2016]

In detail:

- The parametrization is done individually for all detectors and particle components.



Back to reality



$$\varrho(\vec{r}) = f(z,t)$$

- Given a two-dimensional cut through the shower (ground level), the whole shower shape can be reconstructed.

Status of Universality

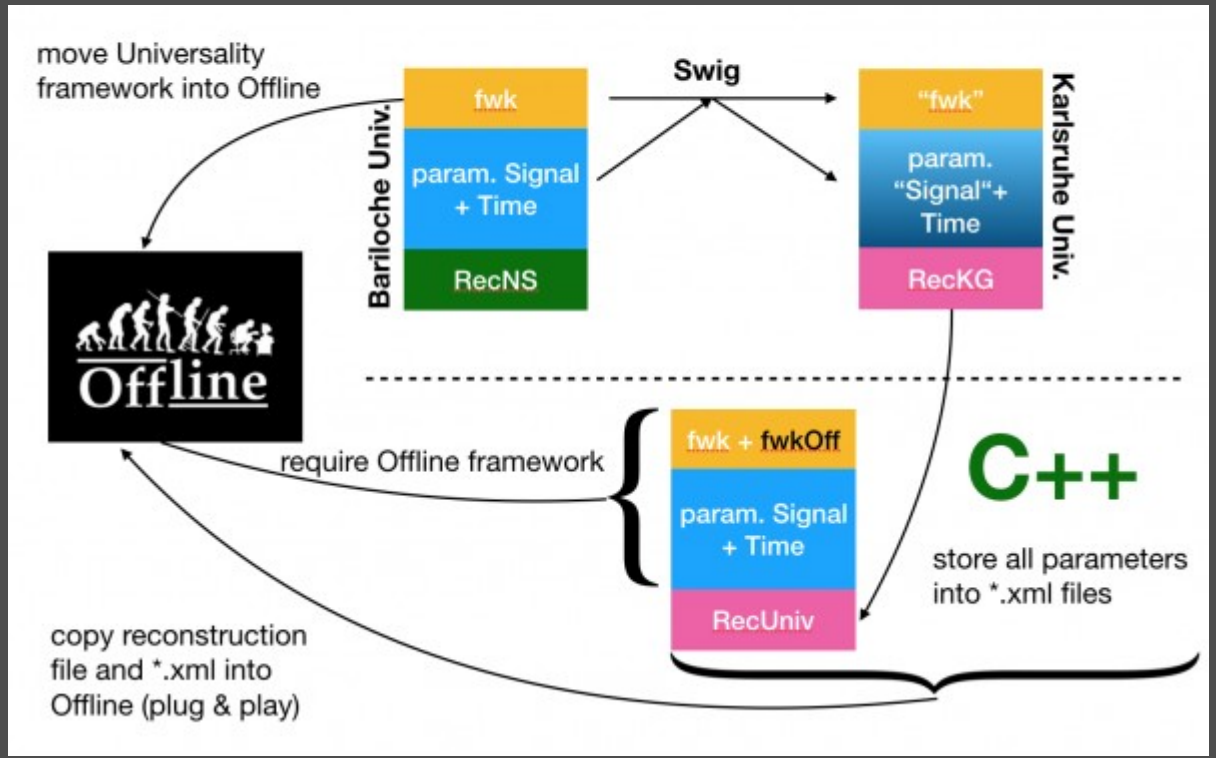
- Two frameworks present: Karlsruhe and Bariloche. Both have their own advantages and disadvantages.
- Both frameworks use an ideal detector response function (not sensitive to fluctuations).
- Both frameworks hard to further develop.

Start over!

→ Universality-v2

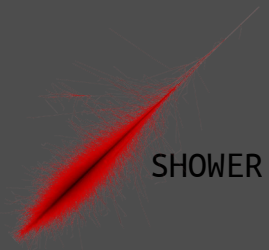
Code overview

- Avoid mixing of programming languages
- Use easy-to-handle file formats
- Use full Offline simulations



[J. Hulsman]

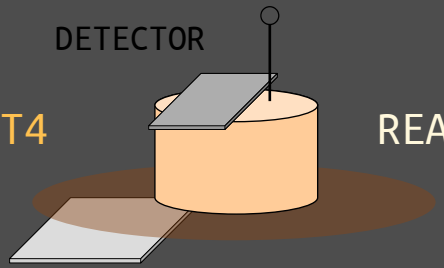
CORSIKA



REAL EVENTS

OFFLINE

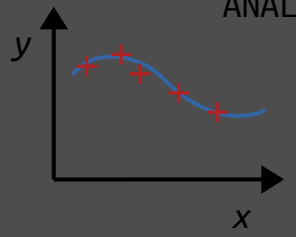
GEANT4



REAL DATA

OFFLINE WITH UNIVERSALITY

SIMULATED DATA



MODEL

UNIVERSALITY-V2

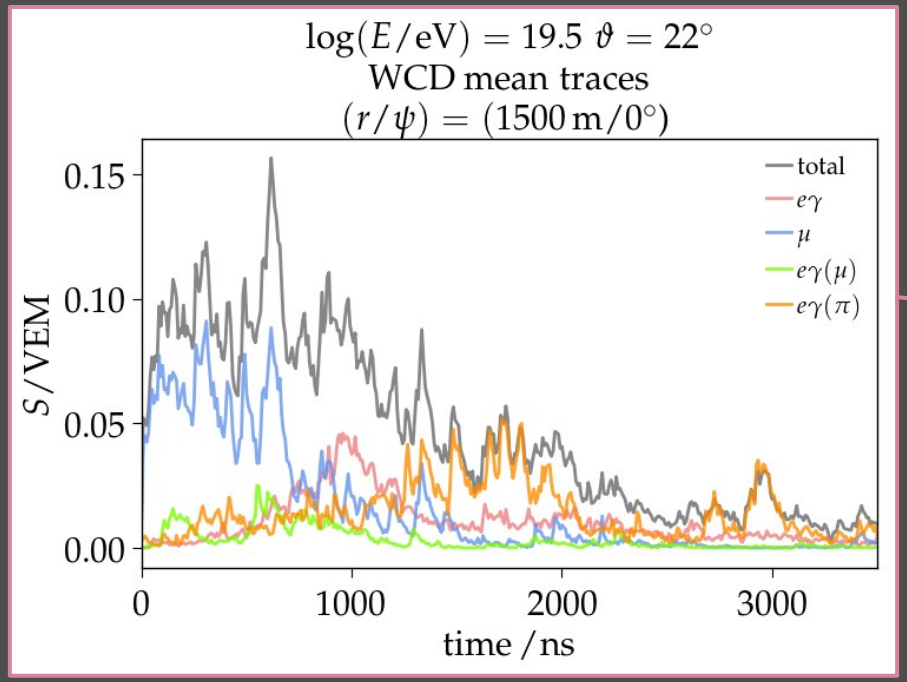
Universality-v2

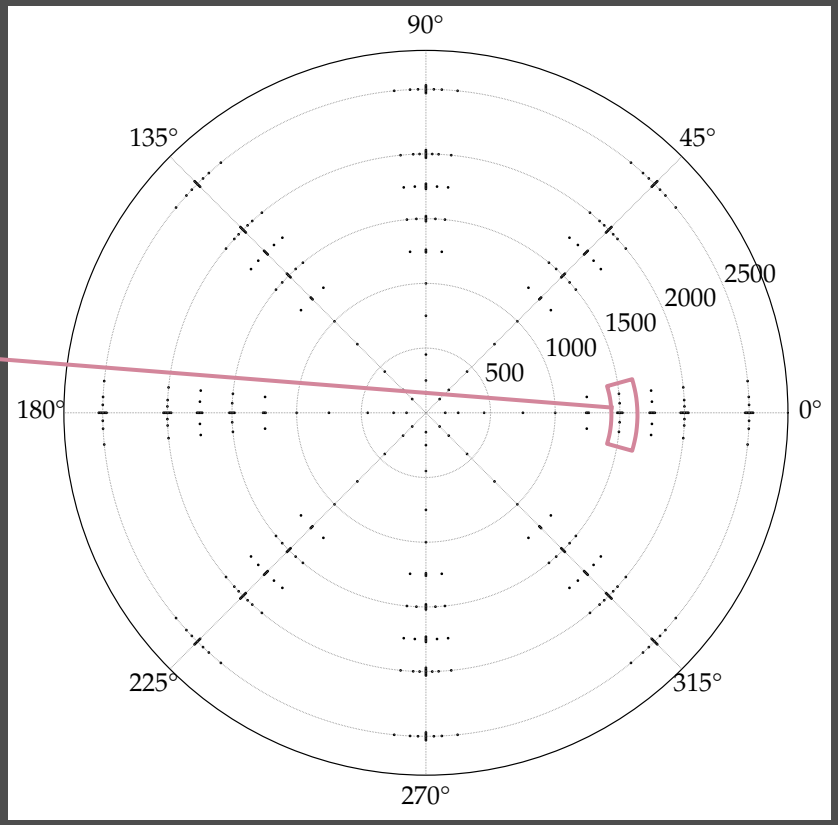
- Currently in development

- Find it on git:

  https://gitlab.ikp.kit.edu/shower-universality/universality-v2

Offline simulations





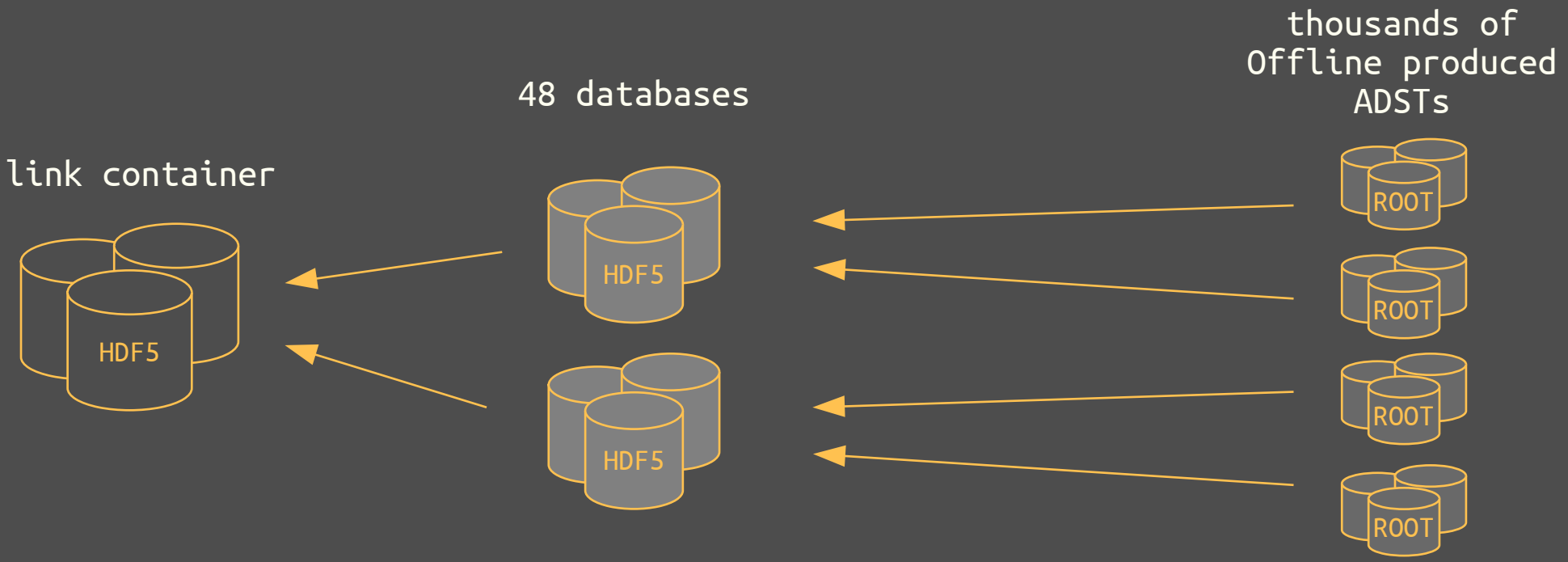
https://gitlab.ikp.kit.edu/shower-universality/universality-v2/blob/master/python/denseGenerator.py.in

Offline simulations

- This way we can account for (and estimate) fluctuations and still produce a mean expected signal.

- Sadly, a little computing effort is required.

Data handling



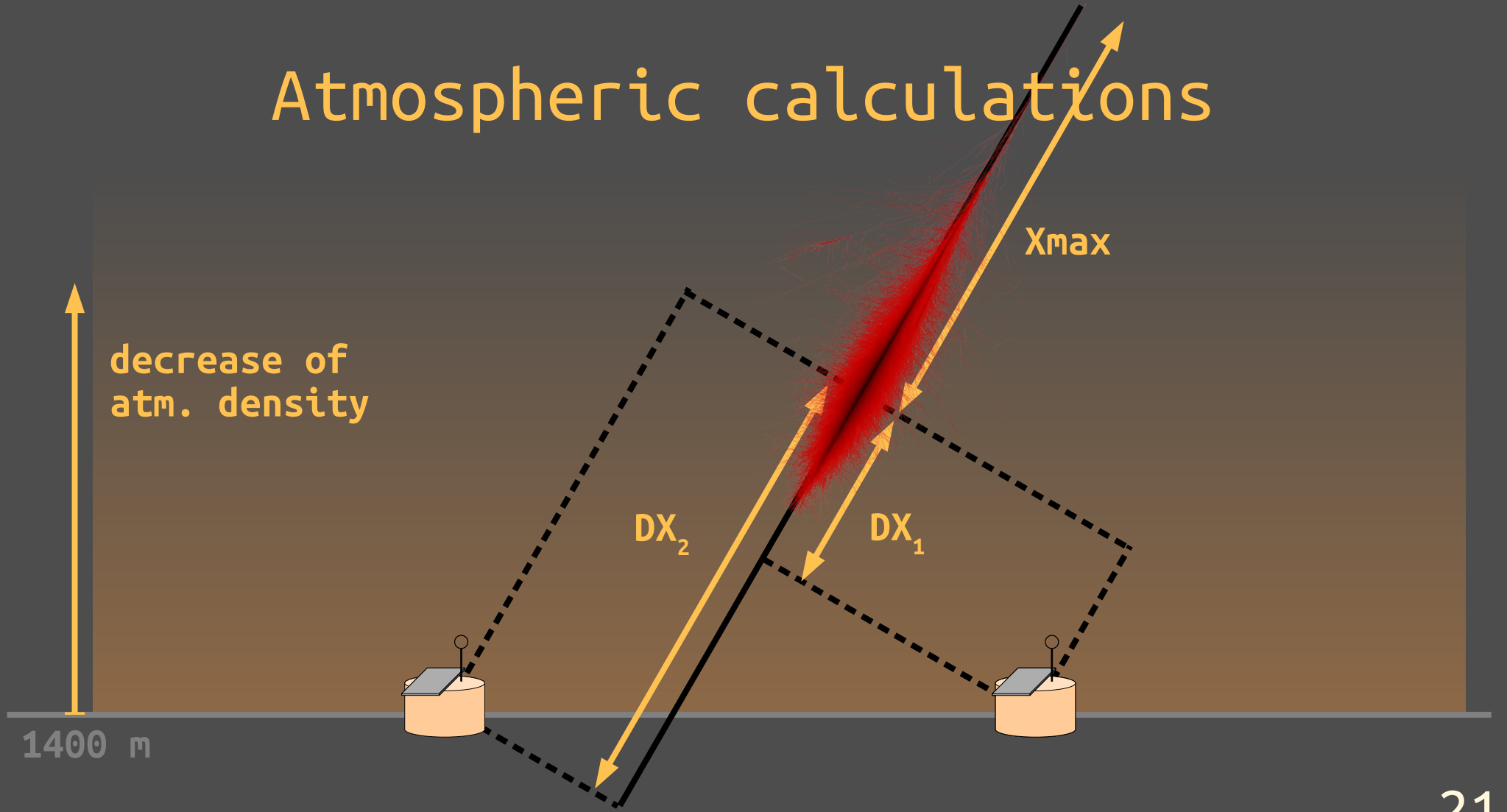
https://gitlab.ikp.kit.edu/shower-universality/universality-v2/tree/master/data/

Data handling

- Data is compressed by a factor of ~100.
- Readout of multi-event-observables in microseconds.

https://gitlab.ikp.kit.edu/shower-universality/universality-v2/tree/master/data/

Atmospheric calculations

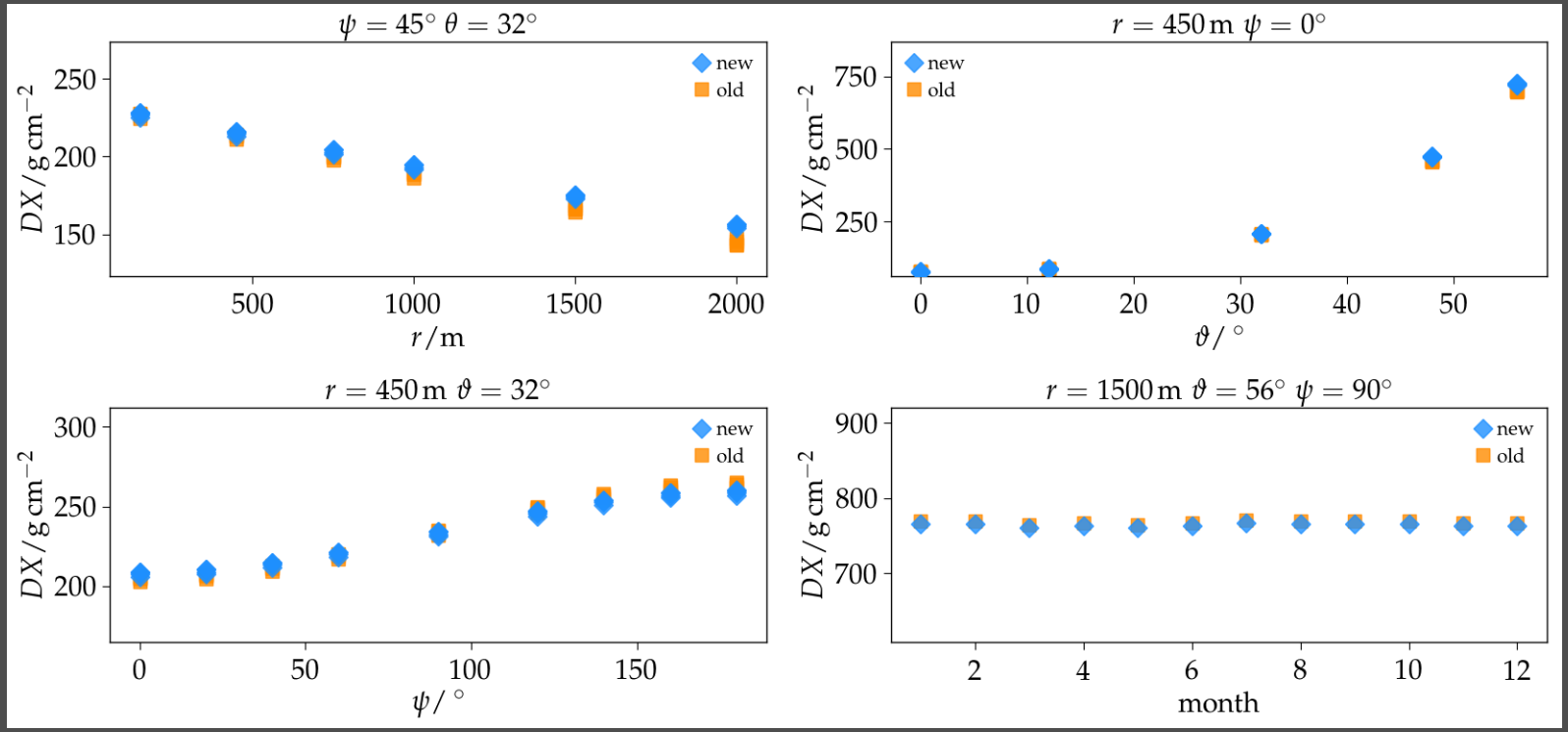


Atmospheric calculations

- Now:
  Calculating DX only with hard-coded monthly CORSIKA atmospheres
  Offline: include/tls/Atmosphere.h
- Future:
  Use the same routines and data as FD (especially for real events), apply monthly corrections by “gauging” technique

https://gitlab.ikp.kit.edu/shower-universality/universality-v2/blob/master/src/PowerShower.cc

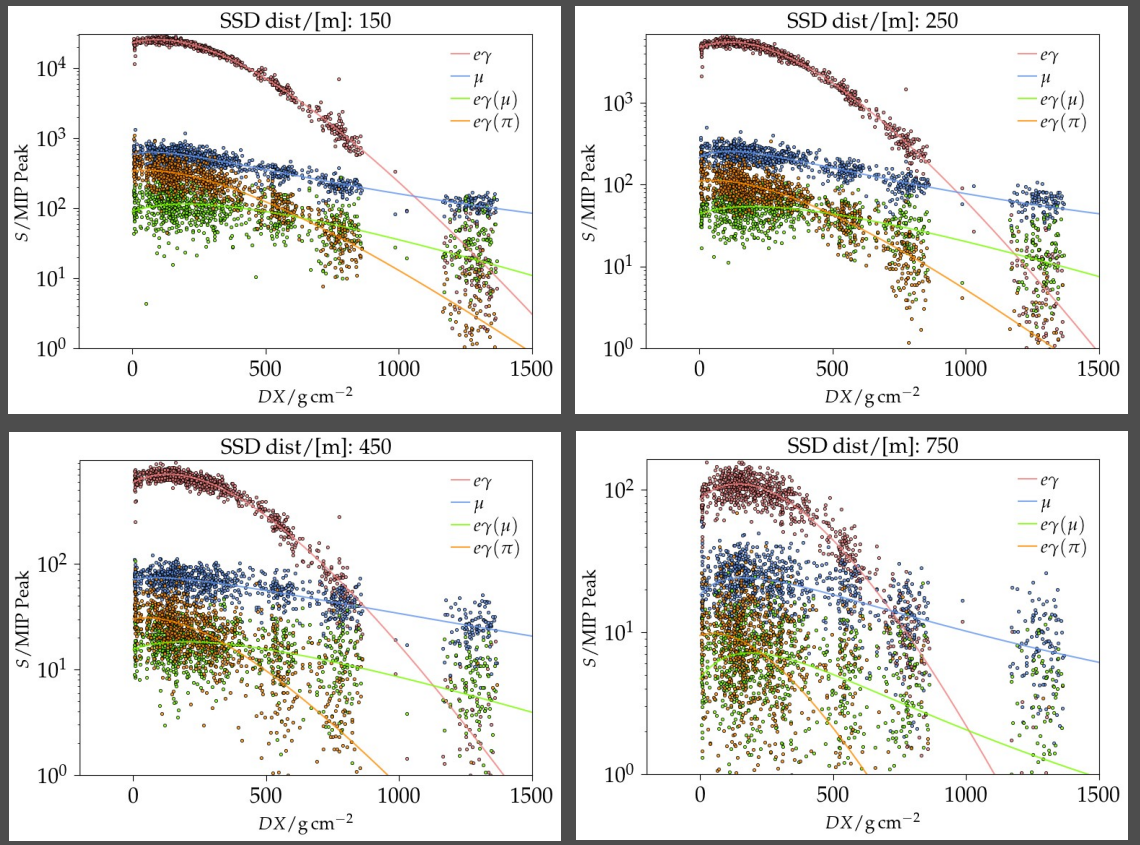
Atmospheric calculations



https://gitlab.ikp.kit.edu/shower-universality/universality-v2/blob/master/misc/CalcDX.cc

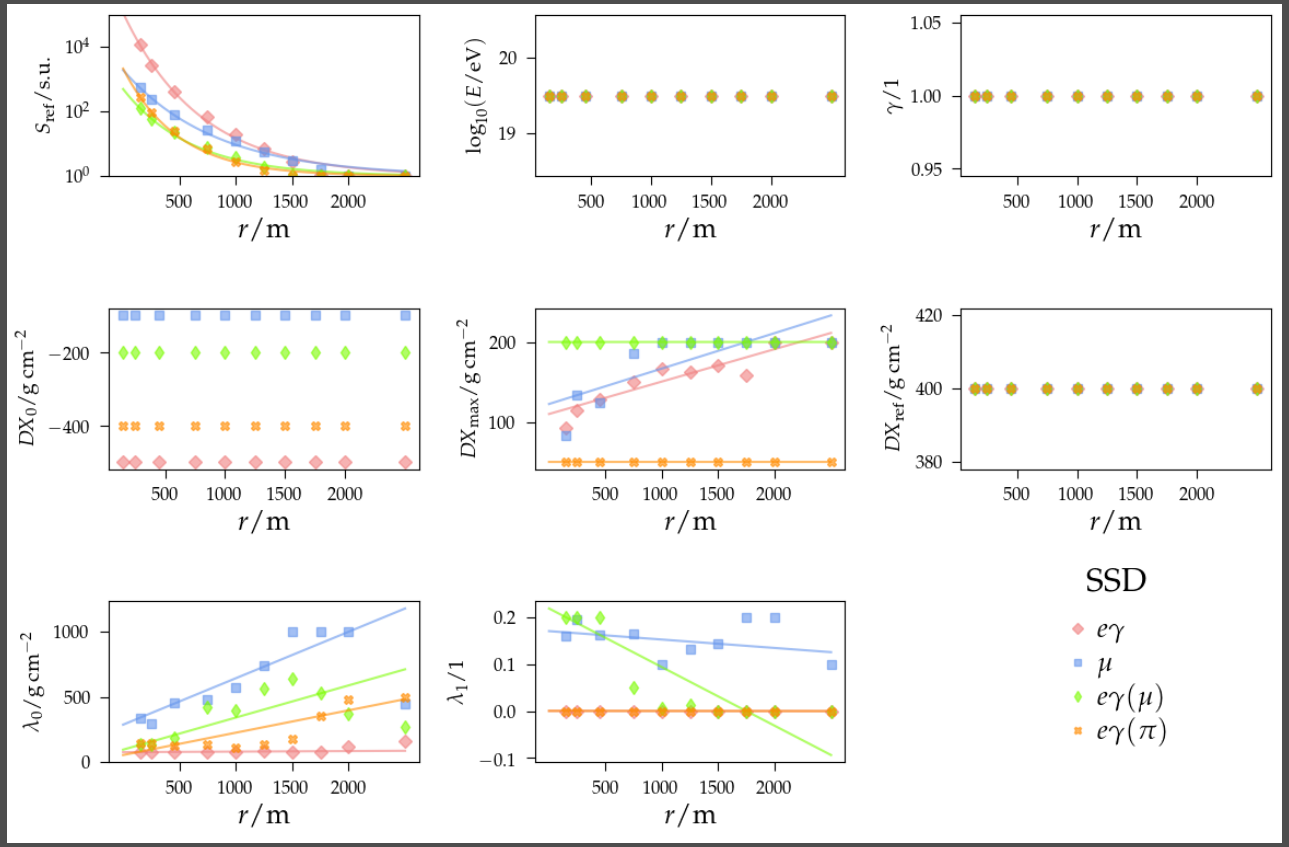
Signal parametrization

- Fit of the modified GH-function for all events and all sampling areas.
- All fits run by Minou.
  [D. Veberic, M. Schimassek]



Signal parametrization

- Combined results yield the model (very preliminary!).
- Results stored in XML format!



Haptic of the framework

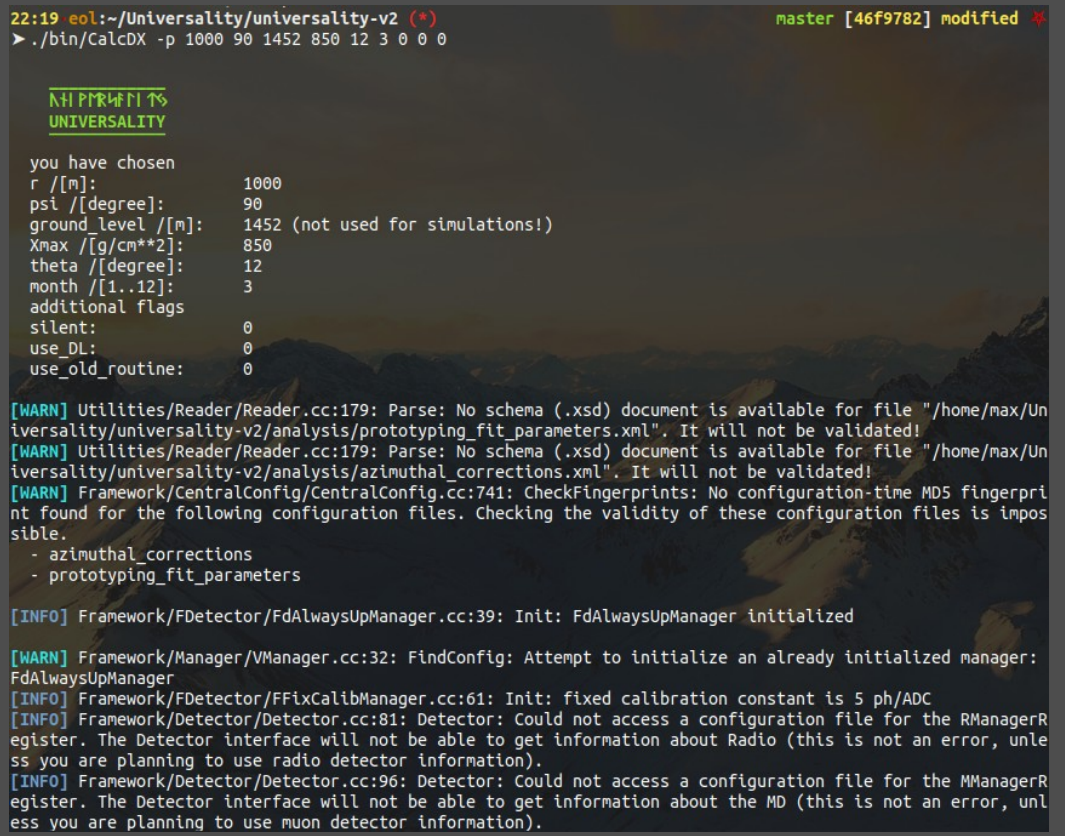
- Idea:
  Plug-and-play
  in the
  bootstrap.xml

- Existent
  parametrizations
  could be imported
  via XML.

```
<?xml version="1.0" encoding="iso-8859-1"?>
<!DOCTYPE bootstrap [
<!ENTITY standardFdIdealDetConfig SYSTEM '$ENV{AUGEROFFLINEROOT}/share/auger-offline/config/standar
<!ENTITY standardSdIdealDetConfig SYSTEM '$ENV{AUGEROFFLINEROOT}/share/auger-offline/config/standar
]>
<bootstrap
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation='$ENV{AUGEROFFLINEROOT}/share/auger-offline/config/bootstrap.xsd'
  xmlns:xlink="http://www.auger.org/schema/types">

  &standardFdIdealDetConfig;
  &standardSdIdealDetConfig;

  <!--
      CAVEAT
      this bootstrap is to be used for handling of simulations and
      simulations only. the detector config is therefore the ideal detector
  -->

  <centralConfig>

    <configLink
      id          = "PrototypeSignalModel"
      type        = "XML"
      xlink:href  = "${prefix}/analysis/prototyping_fit_parameters.xml"/>

    <configLink
      id          = "AzimuthCorrectionParameters"
      type        = "XML"
      xlink:href  = "${prefix}/analysis/azimuthal_corrections.xml"/>

  </centralConfig>

  <parameterOverrides>

    <!-- none -->
```

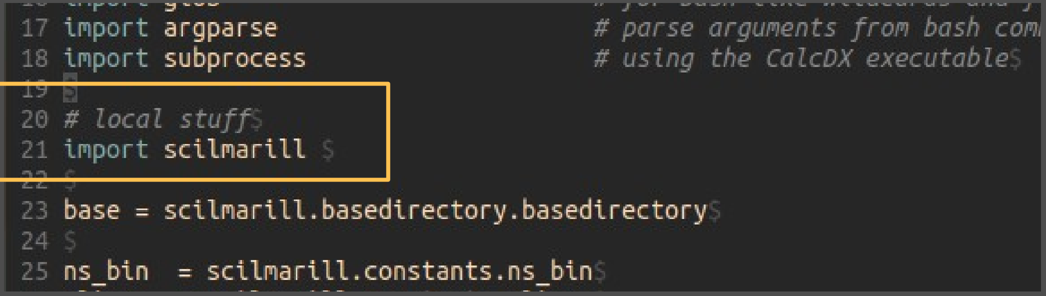
Haptic of the framework

- Offline *and* universality functions are callable and configured with the bootstrap.xml!
- Offline must be installed!



Haptic of the framework

- Comes with a python package to plot data/fits/… directly from HDF5 and XML



Outlook

- O(10) months:
  Flexible, easy to handle framework for Universality

- By the end of my thesis (*hopefully!*):
  Primary mass estimation on event level

Questions?