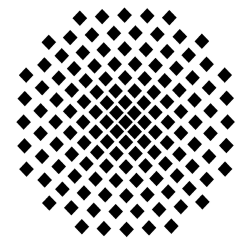
DuMu^x

History and Current State

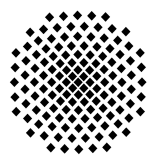
Bernd Flemisch

First DuMu^x User Meeting, Stuttgart, 11./12.6.2015



Pre-DuMu^x: Why LH2 Needed a New Simulator

- In the mid-1990s, **MUFTE-UG** was developed: **Mu**ltiphase **F**low, **T**ransport and **E**nergy on top of **U**nstructured **G**rids.
- **Successfully** extended and used for more than ten years.
- Early 2000s: development and support of **UG stopped** (at least for LH2).
- Implementation of new model (coupling) concepts became **increasingly difficult**.
- 2006: decision to build upon a **new framework**.
- Search for **appropriate candidates** until the end of 2006.



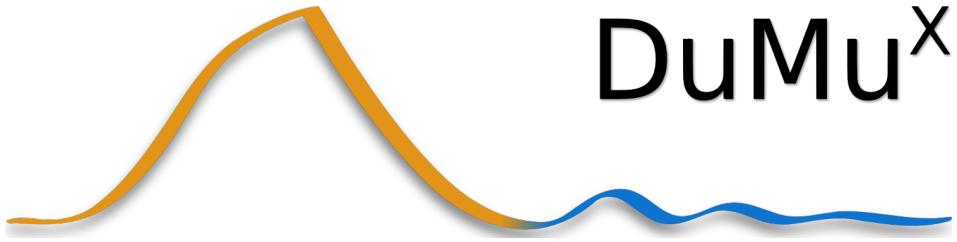
DUNE: Distributed and Unified Numerics Environment

- **Developed** by scientists in Aachen, Bergen, Berlin, Freiburg, Heidelberg, Münster, Stuttgart, Warwick.
- **Separation** of data structures and algorithms by abstract interfaces.
- Efficient implementation using **generic** programming techniques.
- **Reuse** of existing FE packages with a large body of functionality.
- Current stable **release**: 2.3.1 (June 2014).

Core Modules

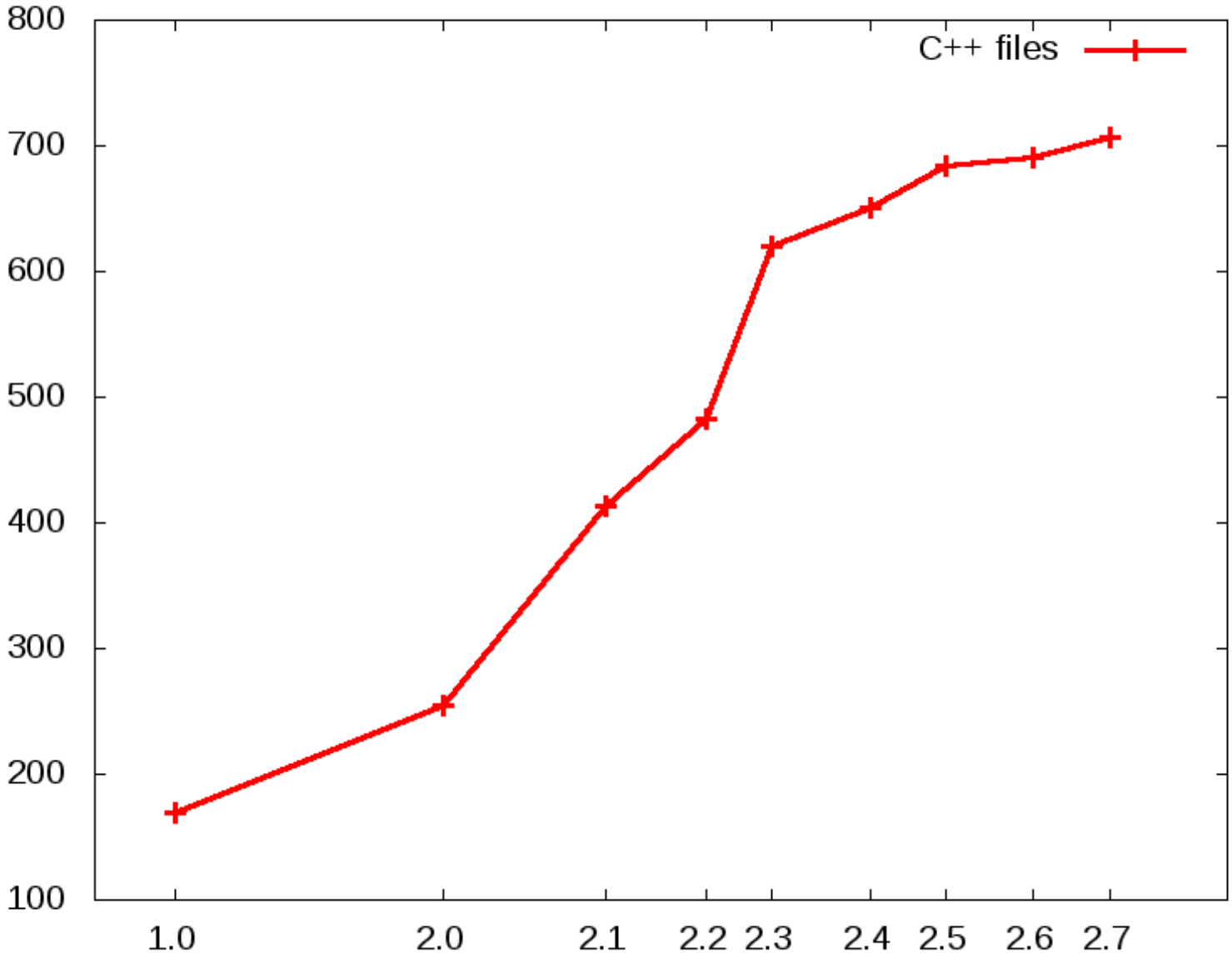
- `dune-common`: basic classes.
- `dune-geometry`: geometrical entities.
- `dune-grid`: abstract grid/mesh interface.
- `dune-istl`: iterative solver template library.
- `dune-localfunctions`: finite element shape functions.

DuMu^x: DUNE for Multi-{Phase, Component, Scale, Physics, ...} Flow and Transport in Porous Media

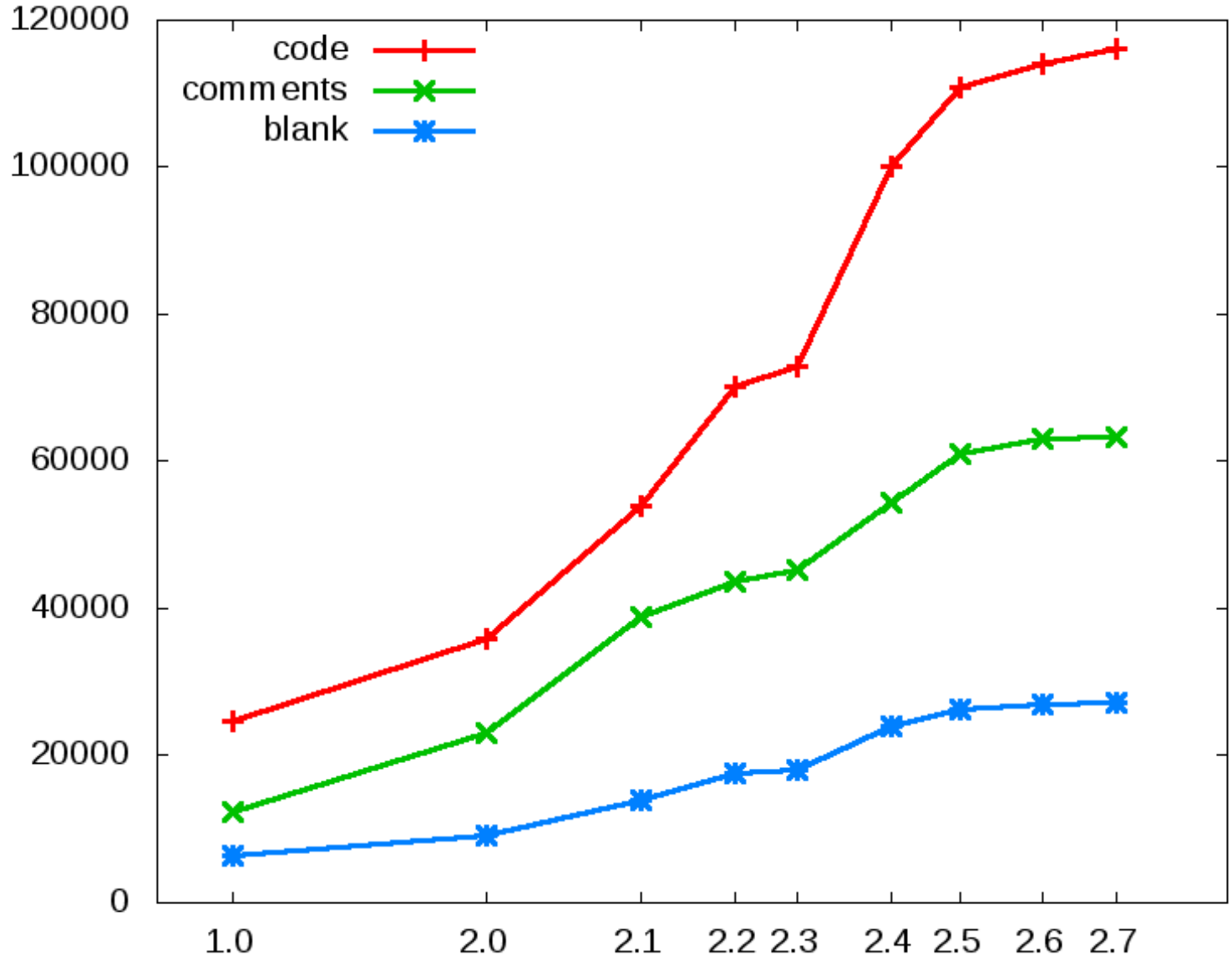


- **Goal**: sustainable and consistent framework for the implementation and application of model concepts and constitutive relations.
- **Developed** by more than 15 PhD students and post docs at LH2.
- 1/2007: development **starts**.
- 1/7/2009: release **1.0**.
- 9/2010: **Split** into stable part and development part.
- 12/2010: Anonymous read access to the **SVN** trunk of the stable part.
- 25/2/2011: release **2.0**, ..., 10/4/2015: release **2.7**.
- 10/6/2015: SVN **revision** 14856.
- More than 800 “real” and unique release **downloads**.

Evolution: C++ Header and Source Files



Evolution: Lines of Code



Available Models: **1.0** 2.0 2.1 2.2 2.3 2.4 2.5 2.6 2.7

Porous Medium Fully-Implicit

`1p`, `1p2c`
`richards`
`2p`, `2p2c`, `2pni`, `2p2cni`

Porous Medium Sequential

`1p`
`2p`, `2p2c`

Free Flow

Geomechanics

Multidomain

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Porous Medium Fully-Implicit

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`2p`, `2p2c`, `2pni`, `2p2cni`
`3p3c`, `3p3cni`
`mpnc`

Porous Medium Sequential

`1p`
`2p`, `2p2c`

Free Flow

`stokes`, `stokes2c`, `stokes2cni`

Geomechanics

Multidomain

Available Models: 1.0 2.0 2.1 **2.2** 2.3 2.4 2.5 2.6 2.7

Porous Medium Fully-Implicit

`1p`, `1p2c`
`richards`
`2p`, `2p2c`, `co2`, `2pni`, `2p2cni`, `co2ni`
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Porous Medium Sequential

`1p`
`2p`, `2p2c`

Free Flow

`stokes`, `stokes2c`, `stokes2cni`

Geomechanics

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Available Models: 1.0 2.0 2.1 2.2 **2.3** 2.4 2.5 2.6 2.7

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richards
2p, 2pdfm, 2p2c, co2, 2pni, 2p2cni, co2ni
3p3c, 3p3cni
mpnc

Porous Medium Sequential

1p
2p, 2p2c

Free Flow

stokes, stokes2c, stokes2cni

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`3p`, `3p3c`, `3p3cni`
`mpnc`, `mpnc-nonequilibrium`

Porous Medium Sequential

`1p`
`2p`, `2p2c`

Free Flow

`stokes`, `stokes2c`, `stokes2cni`

Geomechanics

`elastic`, `el1p2c`, `el2p`

Multidomain

Available Models: 1.0 2.0 2.1 2.2 2.3 2.4 **2.5** 2.6 2.7

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`2p`, `2p2c`

Free Flow

`stokes`, `stokesnc`, `stokesncni`

Geomechanics

`elastic`, `el1p2c`, `el2p`

Multidomain

`2cstokes2p2c`, `2cnistokes2p2cni`

Available Models: 1.0 2.0 2.1 2.2 2.3 2.4 2.5 **2.6** 2.7

Porous Medium Fully-Implicit

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`2p`, `2p2c`

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Multidomain

`2cstokes2p2c`, `2cnistokes2p2cni`

Available Models: 1.0 2.0 2.1 2.2 2.3 2.4 2.5 2.6 **2.7**

Porous Medium Fully-Implicit

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Porous Medium Sequential

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2p, 2p2c

Free Flow

stokes, stokesnc, stokesncni

Geomechanics

elastic, el1p2c, el2p

Multidomain

2cstokes2p2c, 2cnistokes2p2cni

Further Capabilities and Characteristics

Spatial Discretization

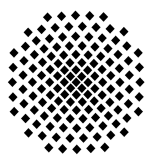
- **Porous medium fully-implicit**: box method, cell-centered FV with TPFA
- **Porous medium sequential**: cell-centered FV with TPFA, MPFA-L, MPFA-O (2p), MFD (2p)
- **Free flow**: box method
- **Geomechanics**: FE for displacement, box method for flow

Grid Adaptivity

- **Porous medium fully-implicit**: from 2.8
- **Porous medium sequential**: yes

Parallelism

- **All** models except free flow and multidomain



The Tip of the Iceberg

DuMu^x (-Stable)

- Contains only a part of the LH2 implementation efforts.
- The part that we consider stable, reasonably well coded, useful for others, and like to share.

DuMu^x-Devel

- The (much bigger) part where our actual research work is done.
- New concepts/algorithms/models are developed/tested/published before they are moved to the stable part.

DuMu^x-Lecture

- Well-described examples/exercises for our lectures.

DuMu^x-Pub

- Enhance transparency: archive and publish the code that has been used for a specific publication (mandatory at LH2 since 2015).