LiLa

EU Project: Library of Labs

Library of Labs

A European Federation for Networked Experiments

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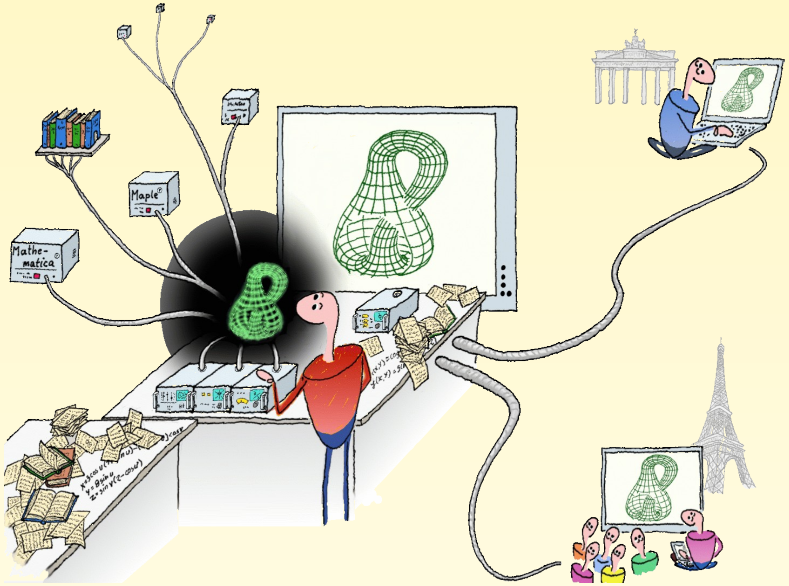
Creator:GIMP Post
CreationDate:Fri J
LanguageLevel:2

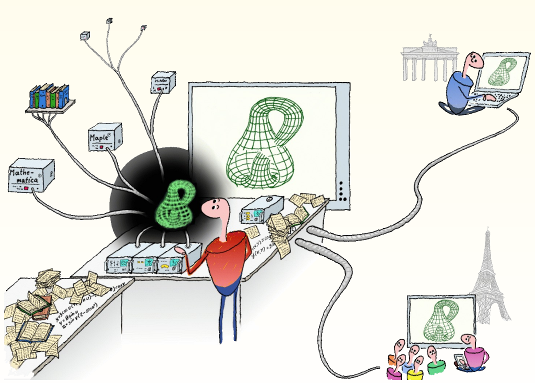
*e***Content***plus*

Thomas Richter (RUS Stuttgart), Harald Scheel (TU-Berlin),
Christian Thomsen (TU-Berlin), Sabina Jeschke (RWTH)

Part A

Motivation and Project Overview

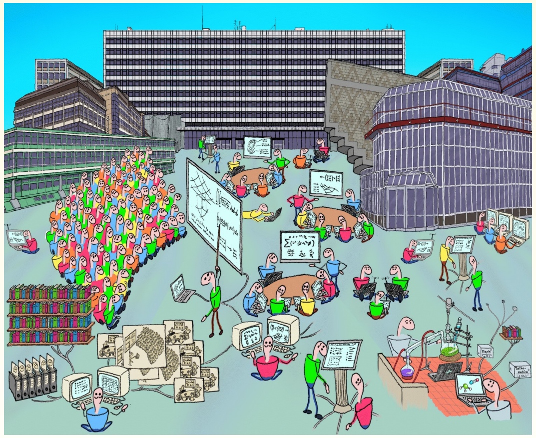




Project Motivation

Analysis of the Status Quo:

- About 30,000 enrolled students in Berlin, 20,000 in Stuttgart, 10,000 in Basel, 86,000 in Thessaloniki
- Undergraduate engineering courses with more than 500 participants are common
- equipment for hands-on experiments is limited, laboratory capacity is limited
- equipment for specialized graduate students becomes more and more expensive



Target:

Create a technical and organisational framework for mutual exchange of experiments accross Europe

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Status of the Engineering Education

Working as an Engineer/Scientist today means...

- Understanding the relation between theory, model and reality
- Cooperation with colleagues

- Using the Computer:
  - as a tool for simulations, organization
  - to perform routine calculations by Computer Algebra Systems

...but in education, we often find:

- separate lectures on experimental and theoretical approach
- assignments to be solved alone

- exercises and homeworks on pen-and-paper algorithms
- no training in using CAS

How to address these issues?

- eLearning can provide bridges between experiment, model and theory
- make experimens available anytime anywhere for direct comparison
- to allow collaborative access to experiments, to compare them

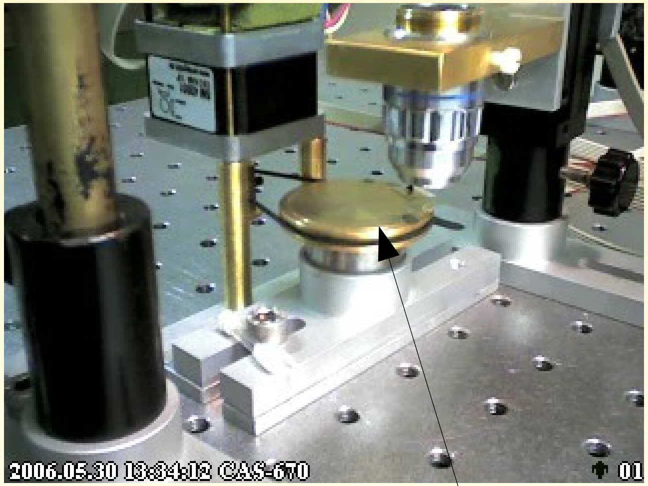
- Hardware: provide campus-wide WLAN access
- Software: Moodle, Maple, LabView, Virtual Laboratories
- ⇒ “Labs on Laptops”

Definition of Remote Experiments

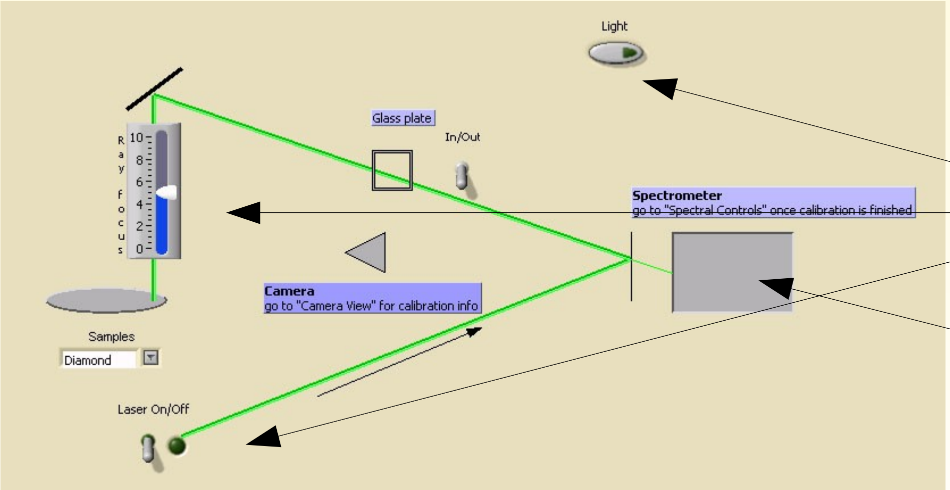
What is a Remote Experiment?

- Real experiments in a laboratory
- Remotely controlled
- Investigation of real objects
- Electronic data exchange possible

Raman Spectroscopy



Sample Selection



Controls

Meter

Definition of Virtual Laboratories

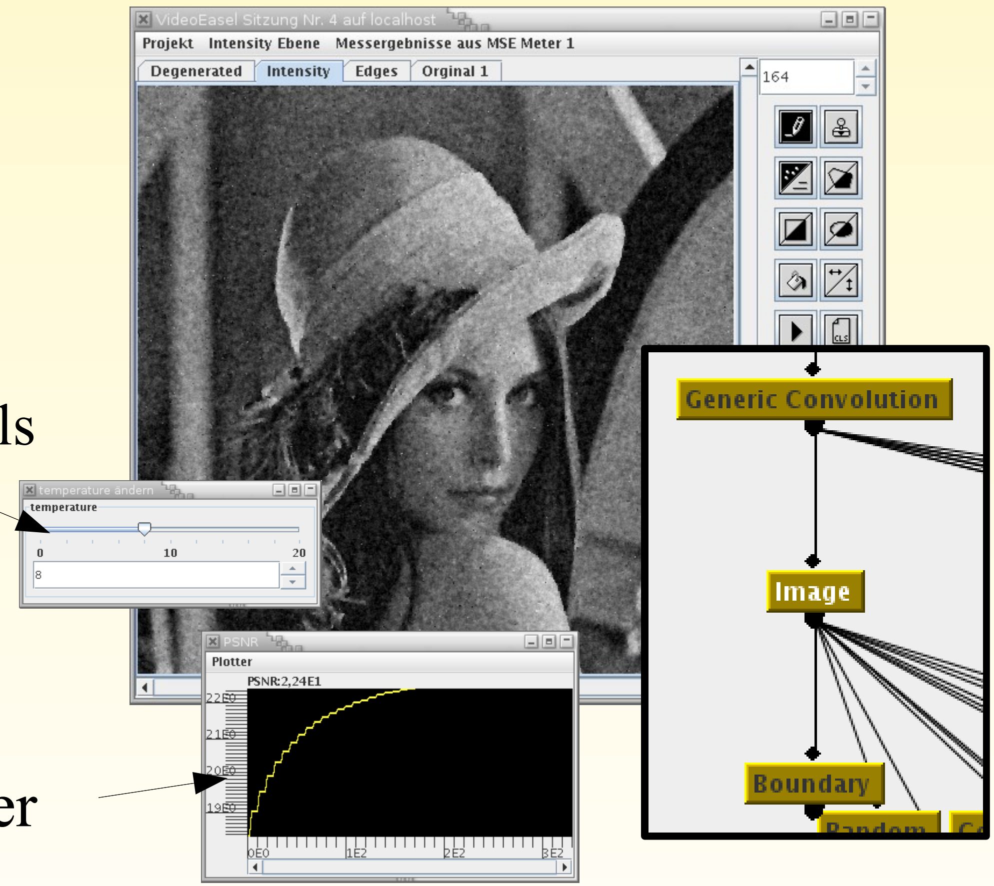
What is a Virtual Laboratory?

- Computer program using „real“ lab metaphor
- Idea: Design, setup and carry out experiments
- Simulation framework
- Simulate real physical devices
- ..or theoretical concepts and objects.

Image Denoising

Controls

Meter



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Remote and Virtual Experiments as Complementary Concepts

Remote Experiments

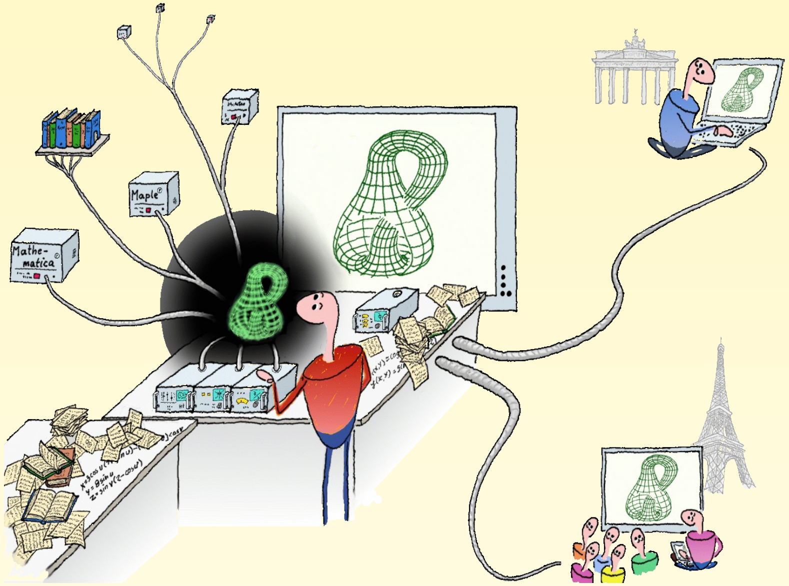
- Experimental Sciences
- for schools, universities and industrial training
- for teaching and research purposes

- experimental access to real experiments over the internet
- share access to large or expensive setups for scientists
- make labs available for large classes

Virtual Laboratories

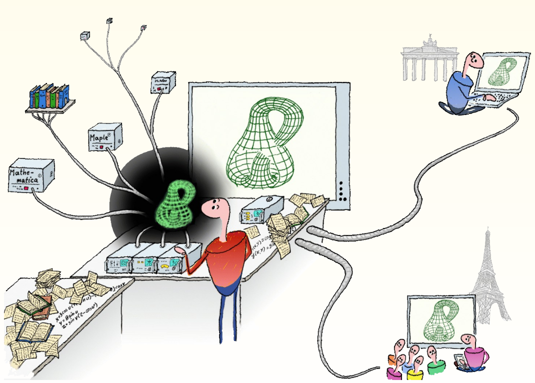
- Experimental and theoretical sciences, including math
- for schools, universities and industrial training
- for teaching and research purposes in mathematics or theoretical fields

- permanent availability of additional experiments
- enhancement of experiment capacity
- relaxes resource or security constraints
- phenomenon presented in „pure“ form
- trial-and-error approach



Part B

On Remote Experiments

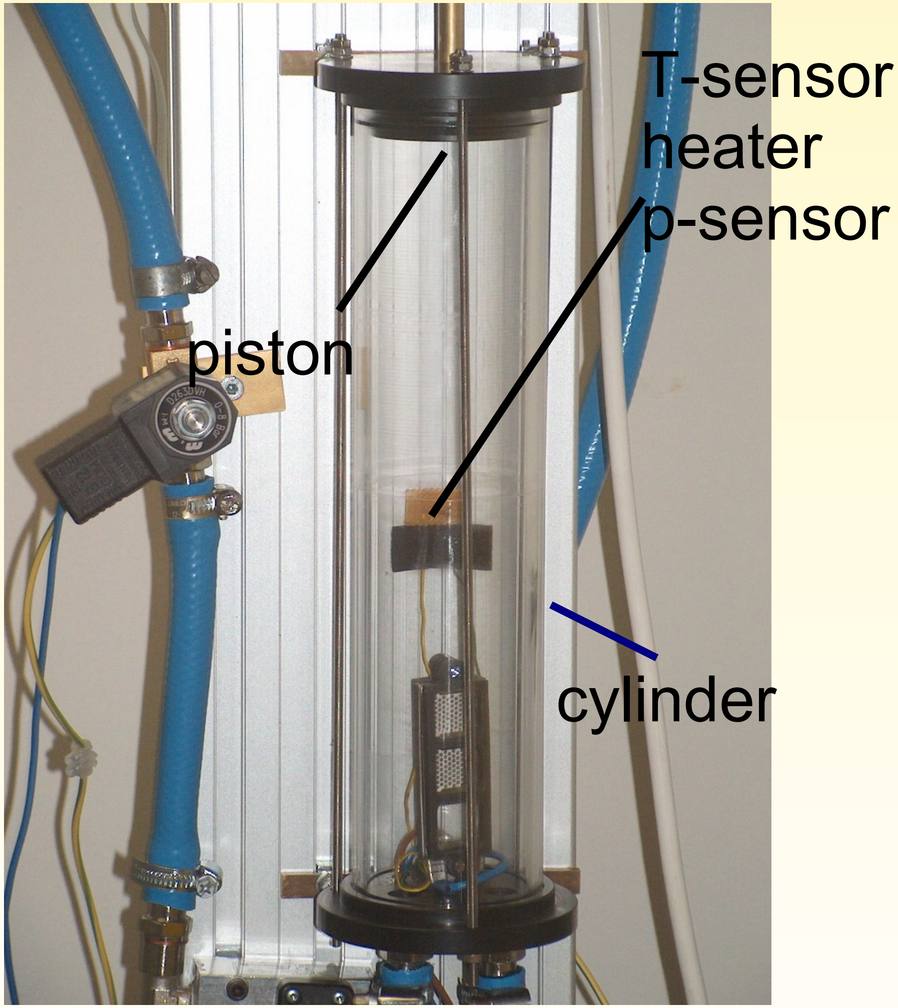


Example: The Ideal Gas

- volume adjustable by the position of the piston

- temperature adjustable by heater

- pressure can be determined by sensor



Now, in the experiment one can validate the ideal gas relation.

for example:

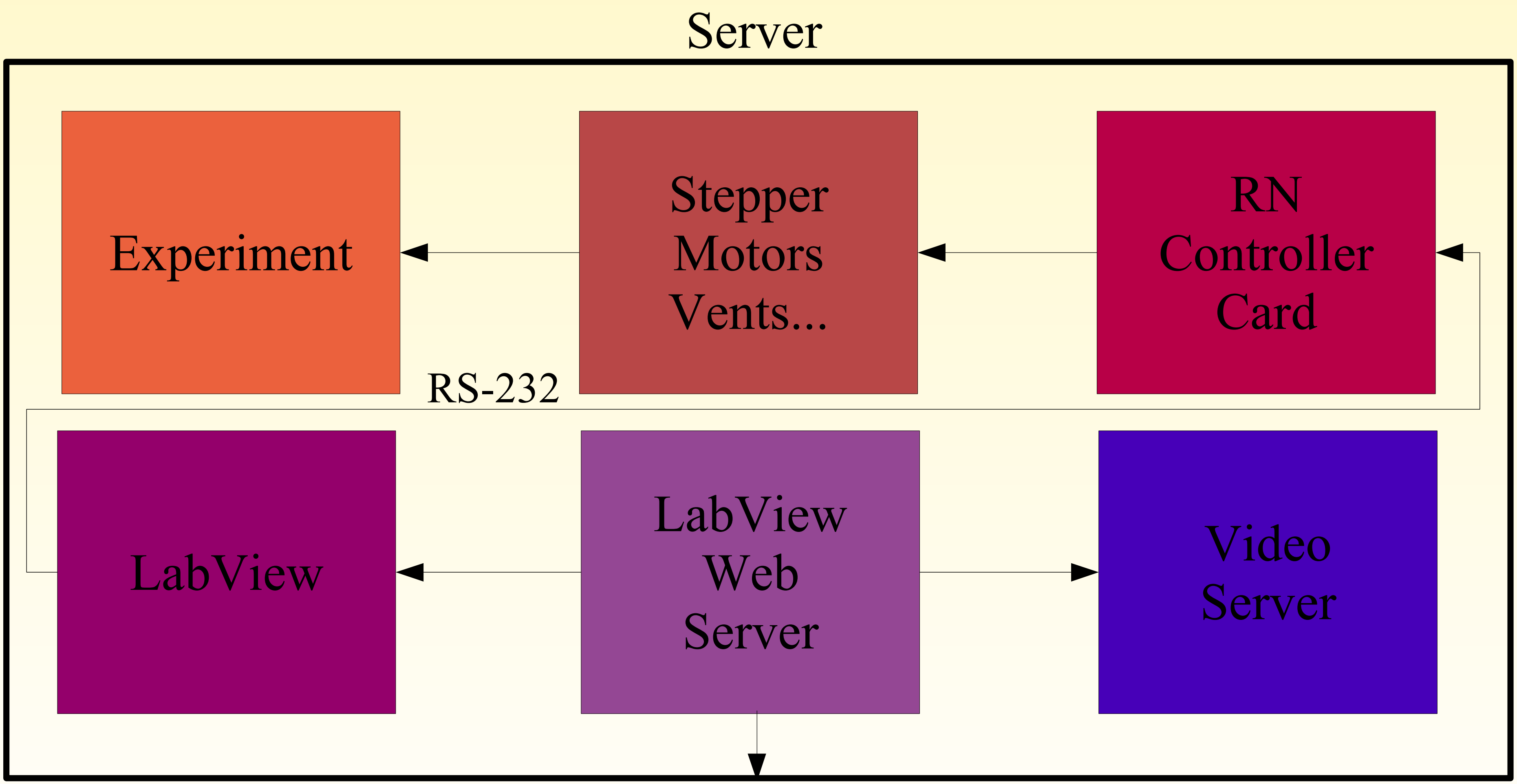
Boyle-Mariotte pV = const. (for T=const.)

Gay-Lussac V/T= const. (for p=const.)

Some Examples of Existing Experiments

- Solar Cell
- Spectrum of Light Sources
- pV Diagram of Ideal Gas
- Fraction on Double Slit
- Capacitor
- Raman Spectrography
- Radioactivity
- Hysteresis
- Transistor

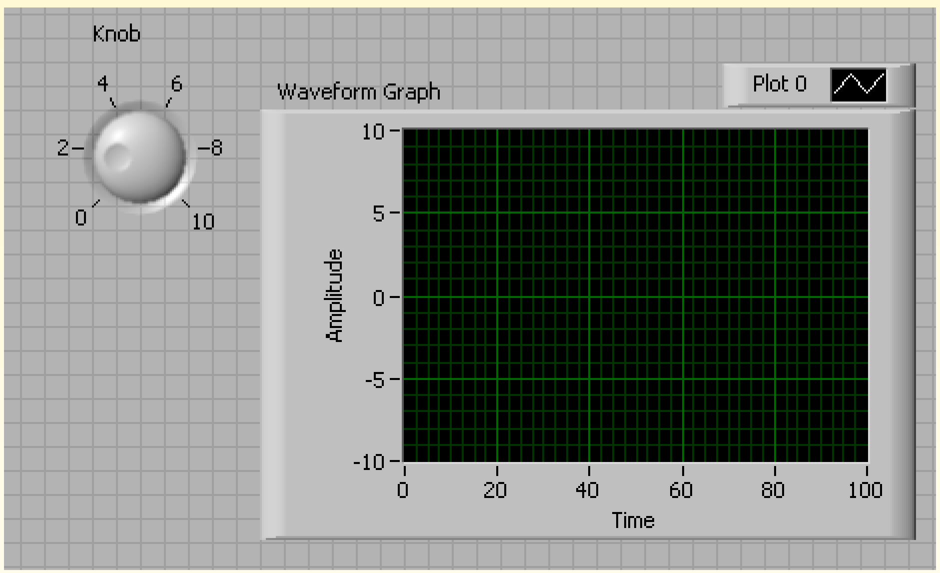
Using LabView to Remote Control Experiments



Internal Workings (2)

LabView: Wiring Hardware and Software to a „Virtual Instrument“ at the Server Side

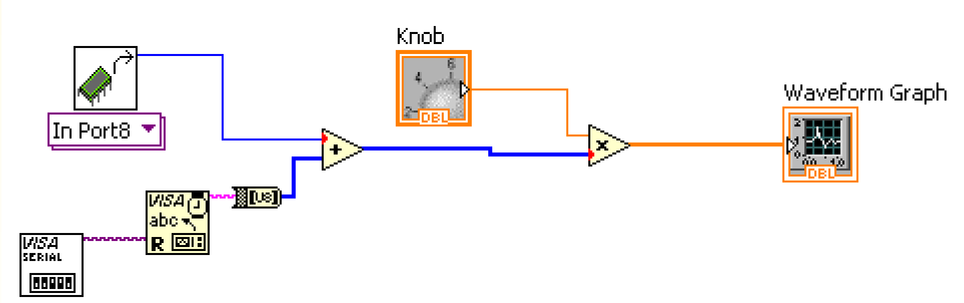
Front Panel



The front panel contains all user interfaces and is made available in the browser

Block Diagram

The block diagram defines the internal data flow and logic of the experiment



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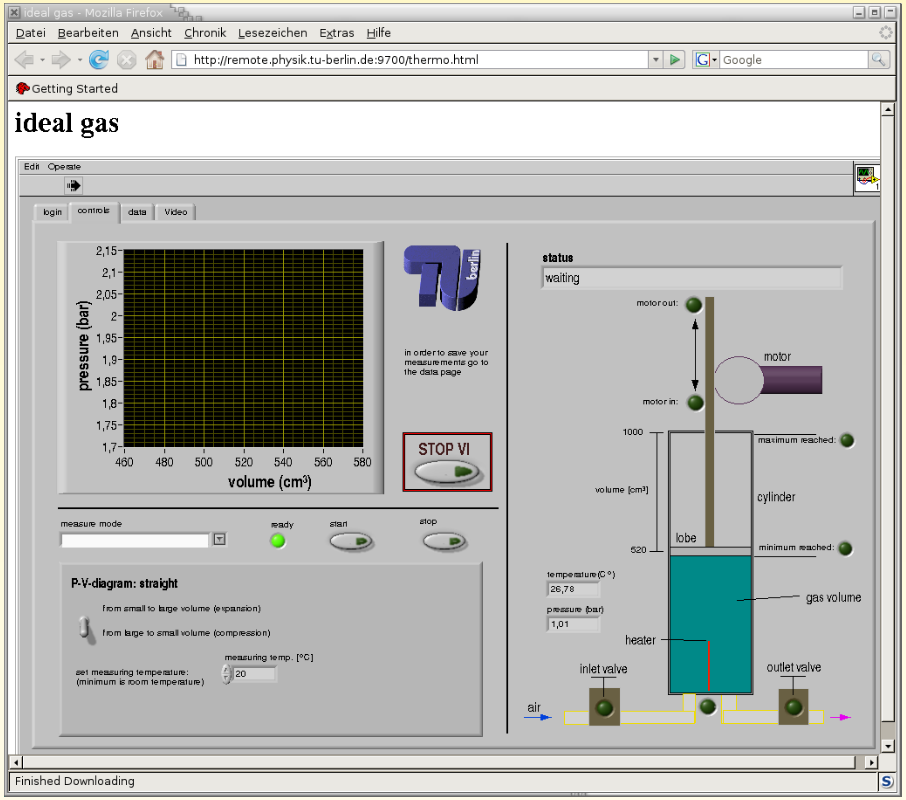
User View



Build-in web server delivers content:

User has to install proprietary browser plug-in (Win32, Linux, Mac...) provided by National Instruments

Problems (will be addressed in LiLa)

- „booking“ of experiments is not possible
- „self-made“ approach of access control
- locked into proprietary LabView protocol (black box, hard to extend)
- „grip“ on experiments is missing

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Collected Experiences in Deployment

- Online Experiments offered now for third time in TU Berlin
- Course: Physics for undergraduate engineering students (1^{st} semester)
- 37 volunteers in first two semesters, will become obligatory soon
- 80% of users had first contact with labs
- 60% had no experience in writing reports
- 40% considered knowledge for remote-controlling experiments important
- 75% appreciated the independence from lab ours
- 75% would recommend RE for other students
- 40% are afraid of experimenting with dangerous materials (radioactivity, chemicals)
- 60% appreciate that they cannot damage the equipment
- 60% of users reported an increase of their computer skills

Experiences: Typical Problems

Observed Issues in the test phase

- Technical problems with LabView caused by insufficient testing (currently, students perform testing)
- Developing remote experiments requires a long time, mistakes in creating the LabView program are not uncommon
- Problems installing the browser plugin (easier for Win, but available for Linux, no 64bit plugin)

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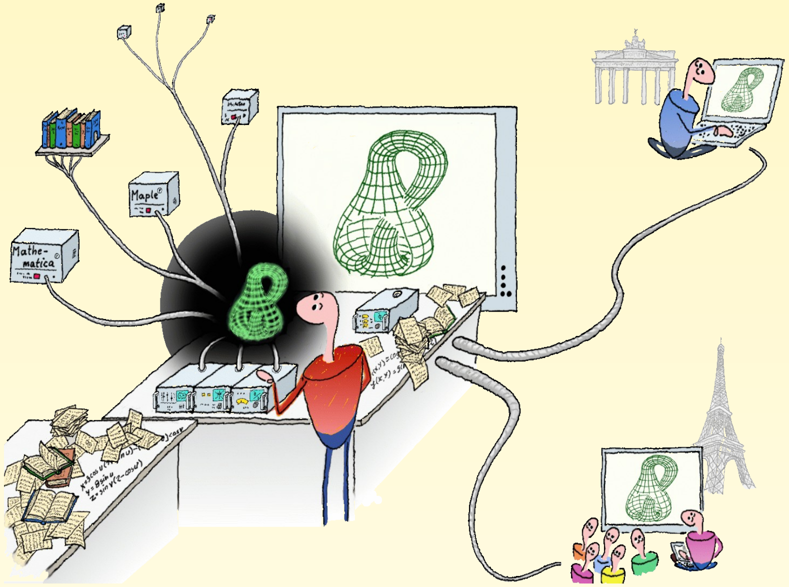
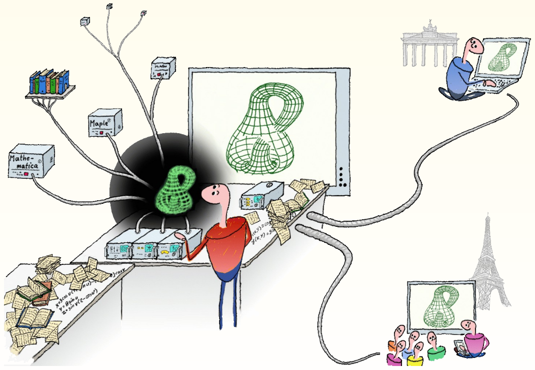


Part C

On Virtual Laboratories



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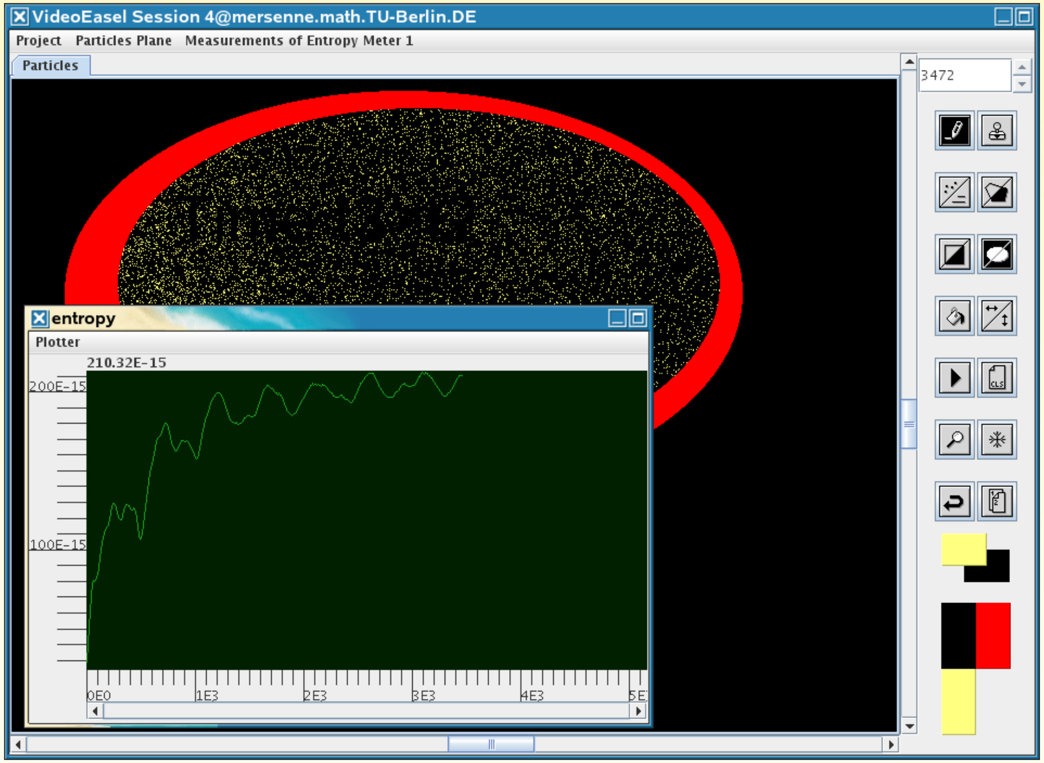
Example: The Lattice Gas

Idealised discrete system for studying the behaviour of gases



Properties:

- Gas consists of individual atoms
- Atoms move in diagonal directions only
- Ideal reflection on walls and between atoms

Phenomena that can be studied:

- Sound waves
- Reflection and refraction of waves
- Entropy and the 2nd law of thermodynamics
- Reversibility objection

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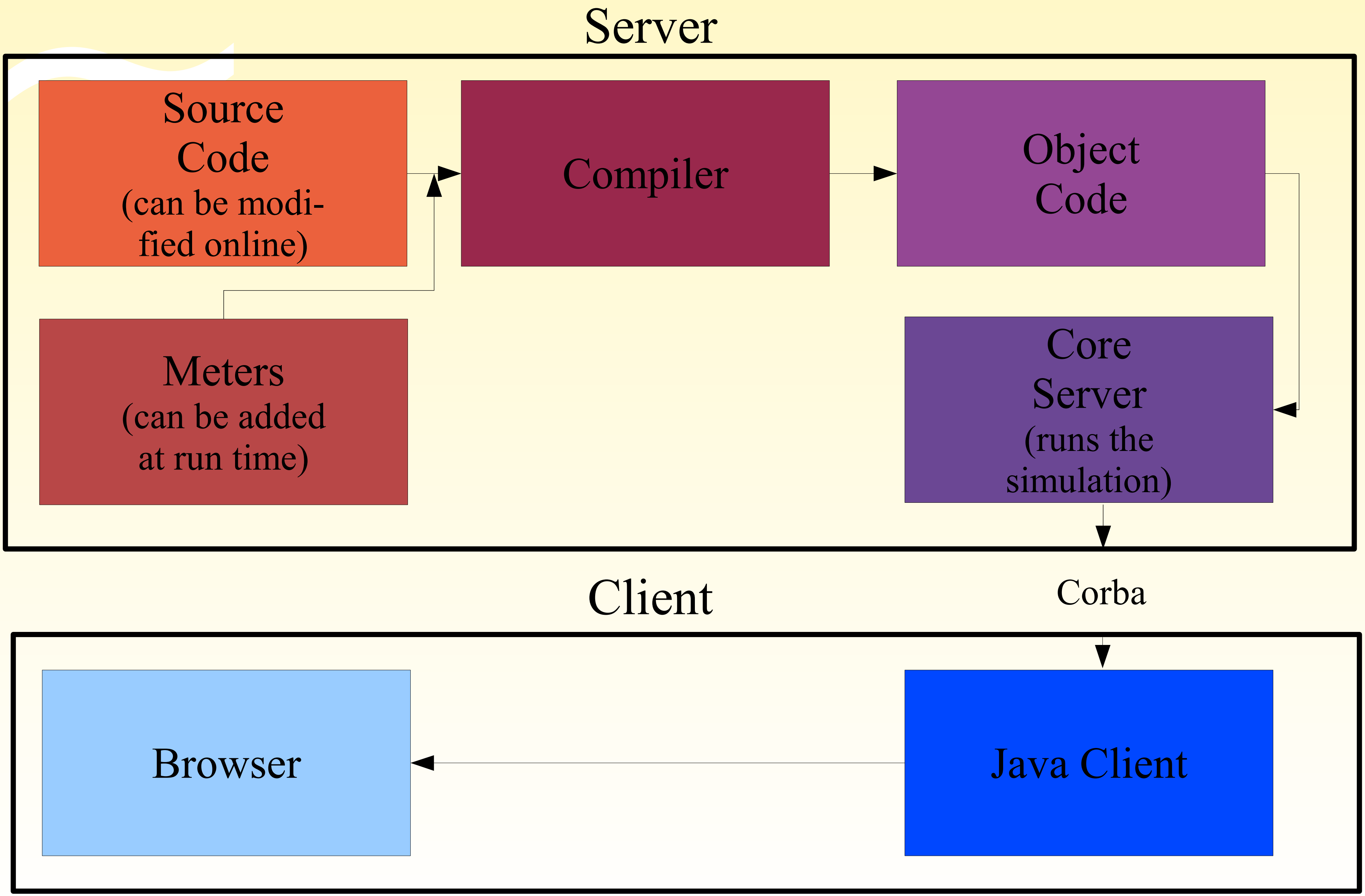
Design of a Virtual Experiment



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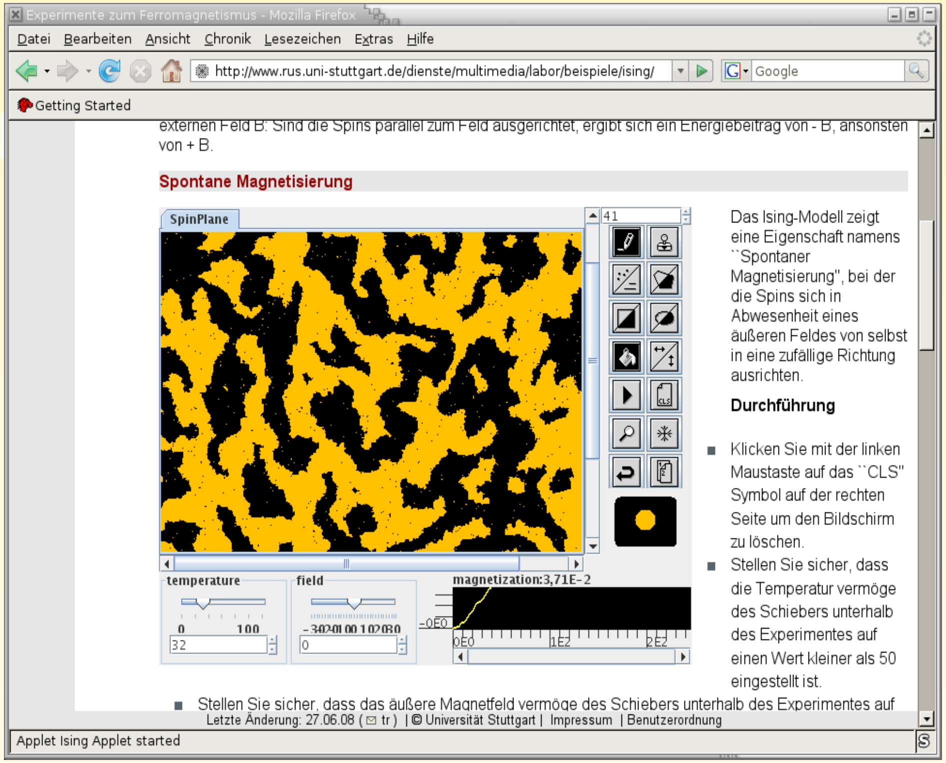
User View



- Standard Java plugin is enough for the user: Experiments are here setup by the staff, including all meters
- Stand-alone Java version is available for download: Full control of the lab, including sources and meters.
- Interfaces for Maple, Java and Python are available.

Problems:

- Modelling is limited to simple discrete systems in the RUS lab
- Hard to find domain of sufficient generality to gain flexibility
- User has to understand that only idealized models are studied **(key point!)**

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Virtual Laboratories: Examples

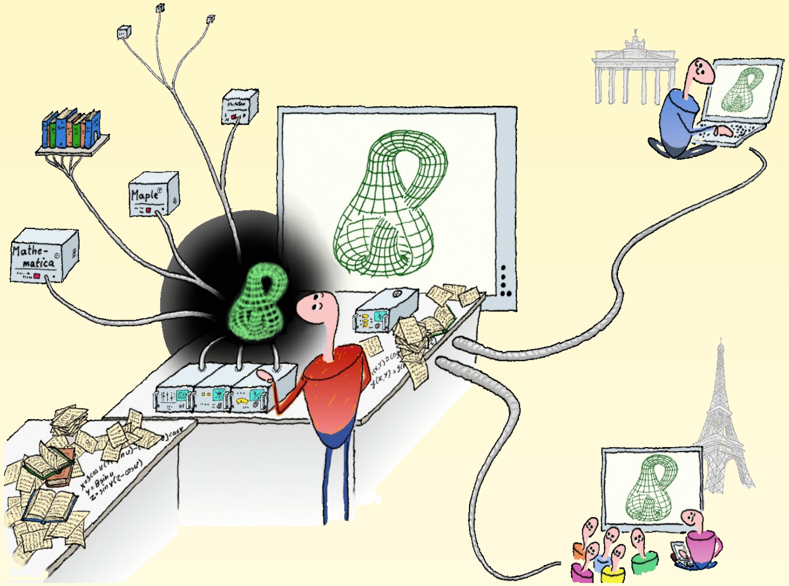
Virtual Laboratories complement remote labs by enabling experiments not possible in reality

Experiments Motivated By Physics

- Ising Model (Magnetism, Hysteresis)
- Lattice Gas (Pressure, Entropy, 2nd Law of Thermodynamics)
- Accoustics (Sound waves, reflection, refraction of waves)

Non-physical Experiment

- Partial Differential Equations
- Image Denoising
- Complete Induction
- Preditor-prey dynamics



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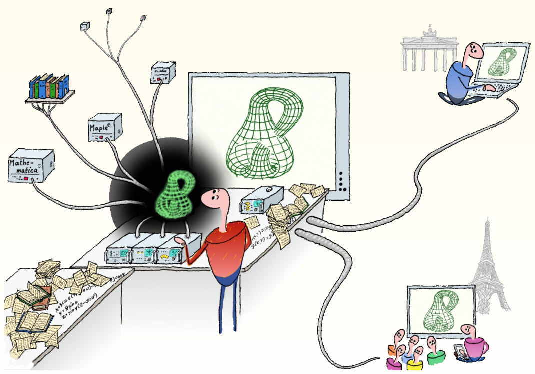
Remote Experiments and Virtual Labs as Complementary Approaches



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Complementary Approaches

Thesis:

- Remote Experiments and Virtual Labs stress different topics of a phenomena that complement the understanding of a physical phenomena
- Students will find differences between what the theory tells, what the simulation returns and what the experimental data says. It is important to understand the limitations of each of them.

Supporting Evidence

- Two examples are given:
  - The ideal gas in theory, model and experiment
  - The phenomena of hysteresis in model and experiment

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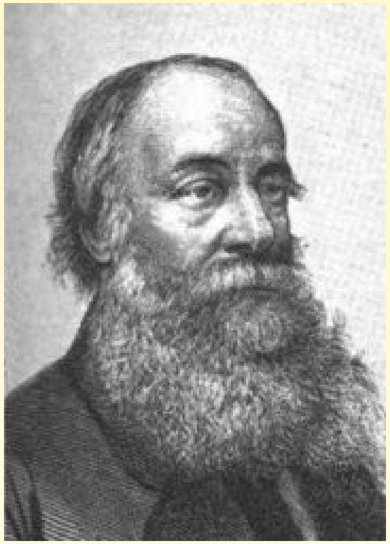
Example 1: Ideal Gases



J. P. Joule
1818 - 1889

R. J. E. Clausius
1822-1888

N. L. S. Carnot
1796 -1823

H. L. F. Helmholtz
1821-1894

Thermodynamics describes large physical systems by empirical variables, e.g. pressure, temperature, volume...

Example: $pV \sim T$ for ideal gases

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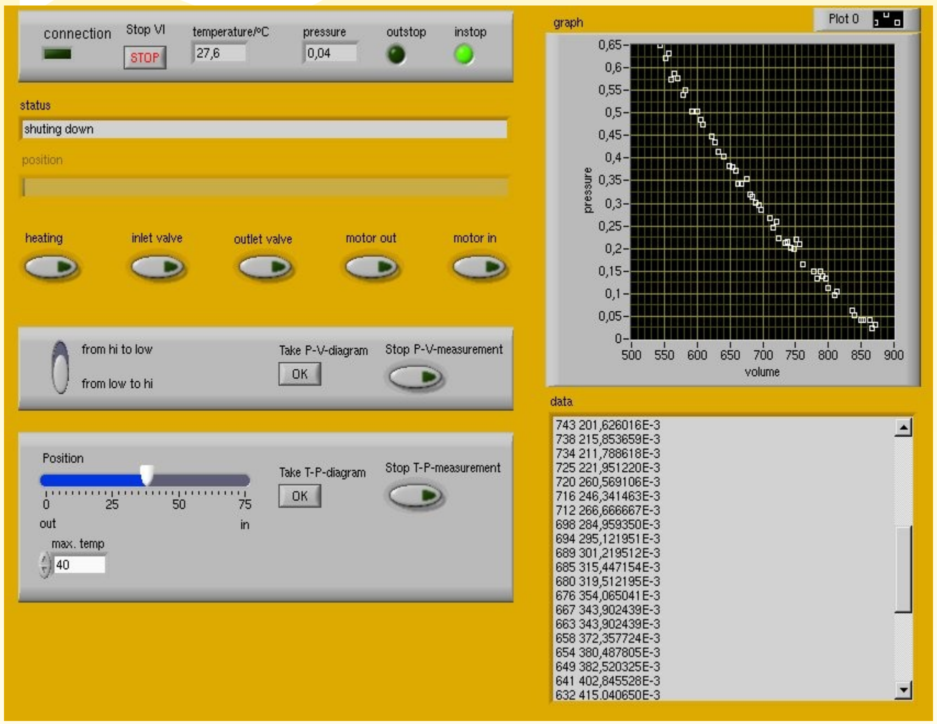
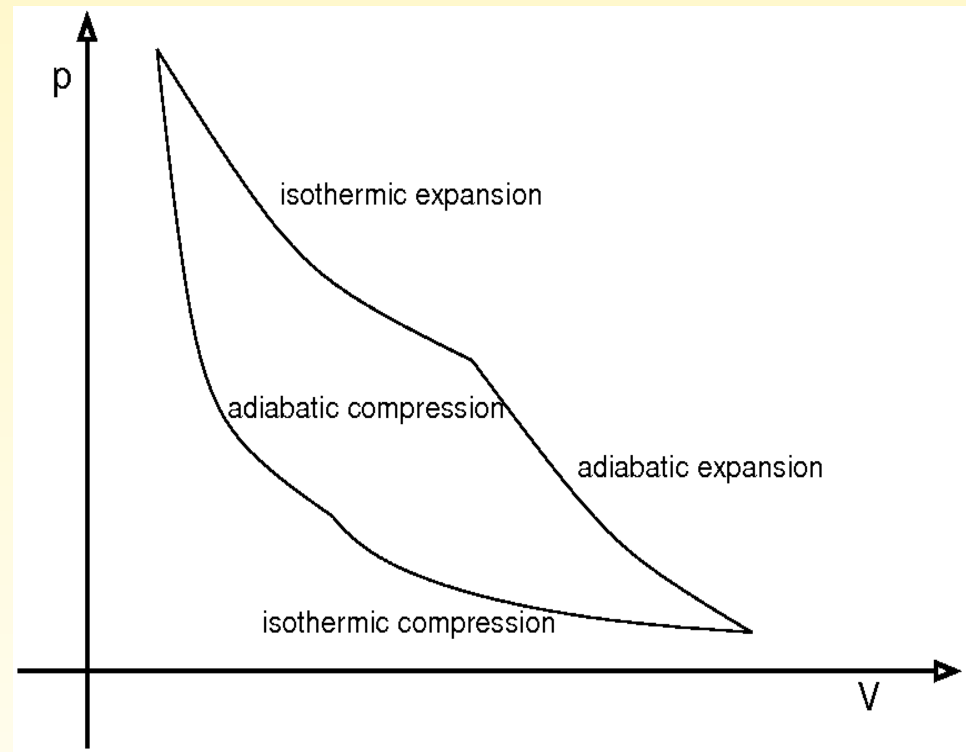
Experiment: The Carnot Cycle



pV diagram of the “real” gas



Idealized pV diagram (Carnot cycle)

Textbooks often idealize the situation for didactical purposes.
Expermental results often look “less pretty”

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The Laws of Thermodynamics

Experience: Thermodynamic engines have a limited efficiency < 1
(measured this in an experiment!)
Experience: Perpetuum mobiles are impossible

1850: “**On the Driving Force of Heat**”: Formulation of the principles of thermodynamics

1. Law: The energy in any isolated thermodynamic system remains constant.

2. Law: The total entropy of any isolated thermodynamic system increases over time, approaching a maximum value.

Rudolf J.E. Clausius
1822-1888

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Boltzmann's Idea and Loschmidt's Objection

Problem: The entropy of a macroscopic system cannot be measured directly, it is an abstract concept.

Boltzmann Idea:

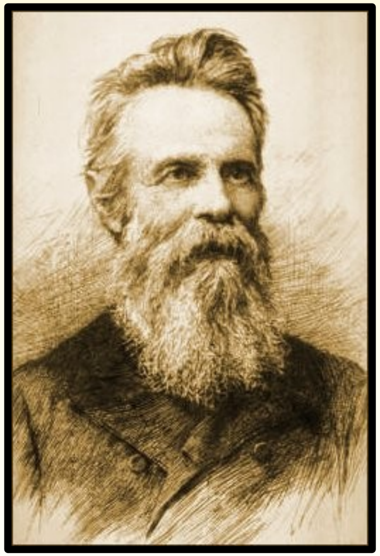
Use laws of Newton-Mechanics and derive the observed gas laws, i.e. consider thermodynamics as a statistical science and define entropy as the amount of unorder of the system.

Real systems are too large: Measure this in a **simulation**. (now to the experiment)

Loschmidt "Umkehreinwand":

Laws of Mechanics have to apply, even if all velocities are reversed! Gas "creeps" back into container falsifying the 2nd Law,in contrast to observations.

Ludwig Boltzmann
1844-1906



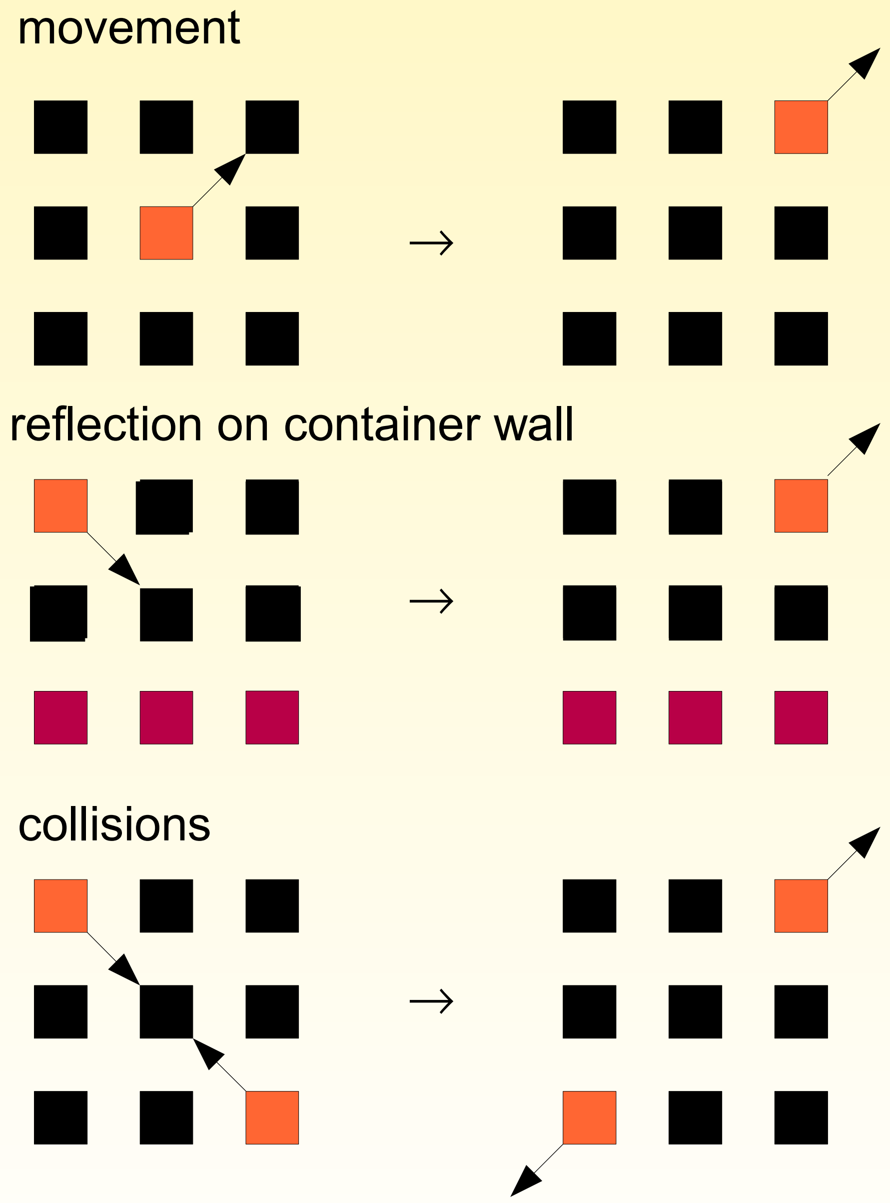
Johann Loschmidt
1821-1895

Lattice Gases as Model

Dynamics of the lattice gas
in the virtual laboratory

HPP-gas (Hardy, Pomeau, dePayssis, 1973):

- 2d-array of sites for particles
- particles move in diagonal directions
- particle interaction preserves energy and momenum



container wall

particle

empty space

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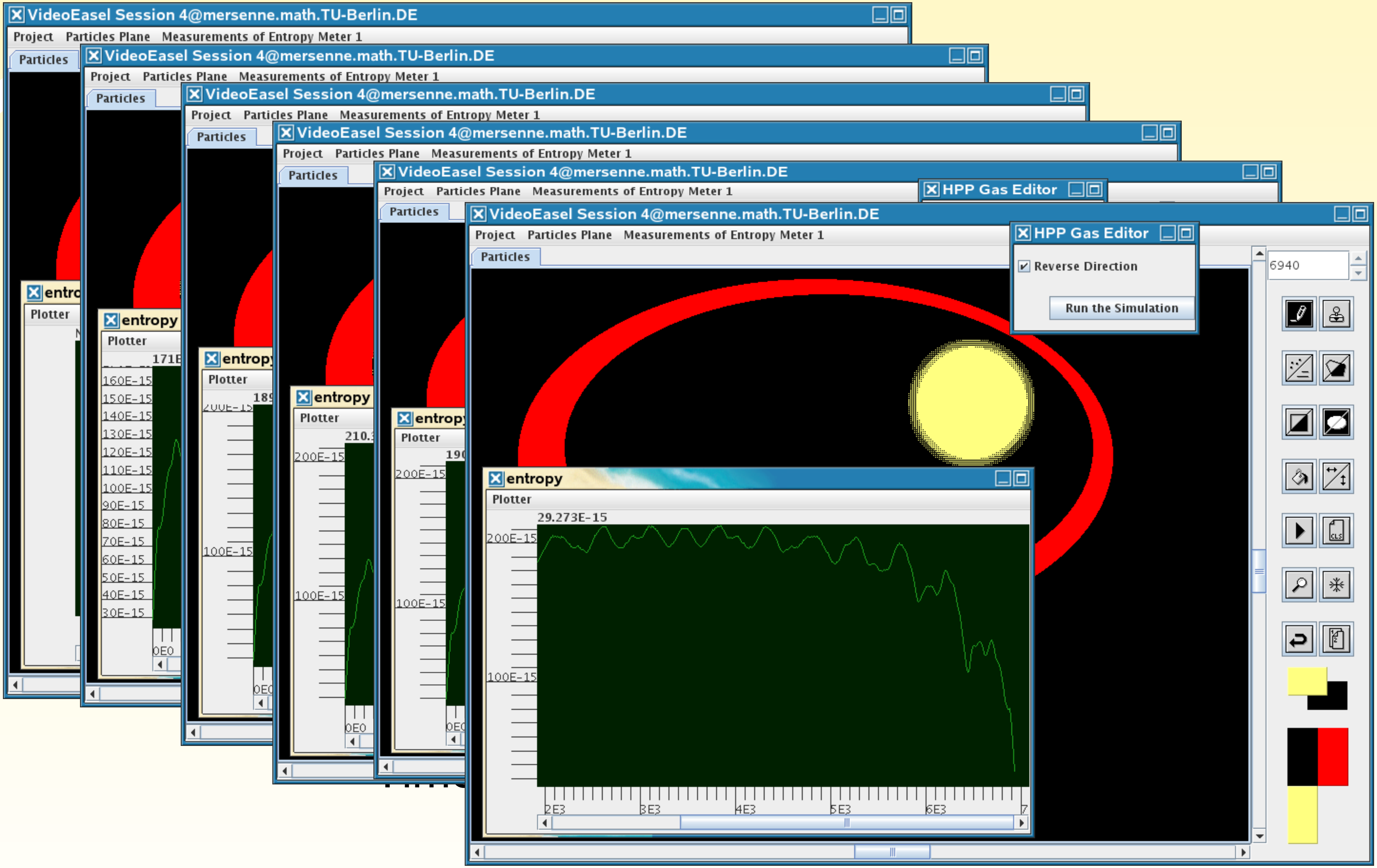
The Experiment



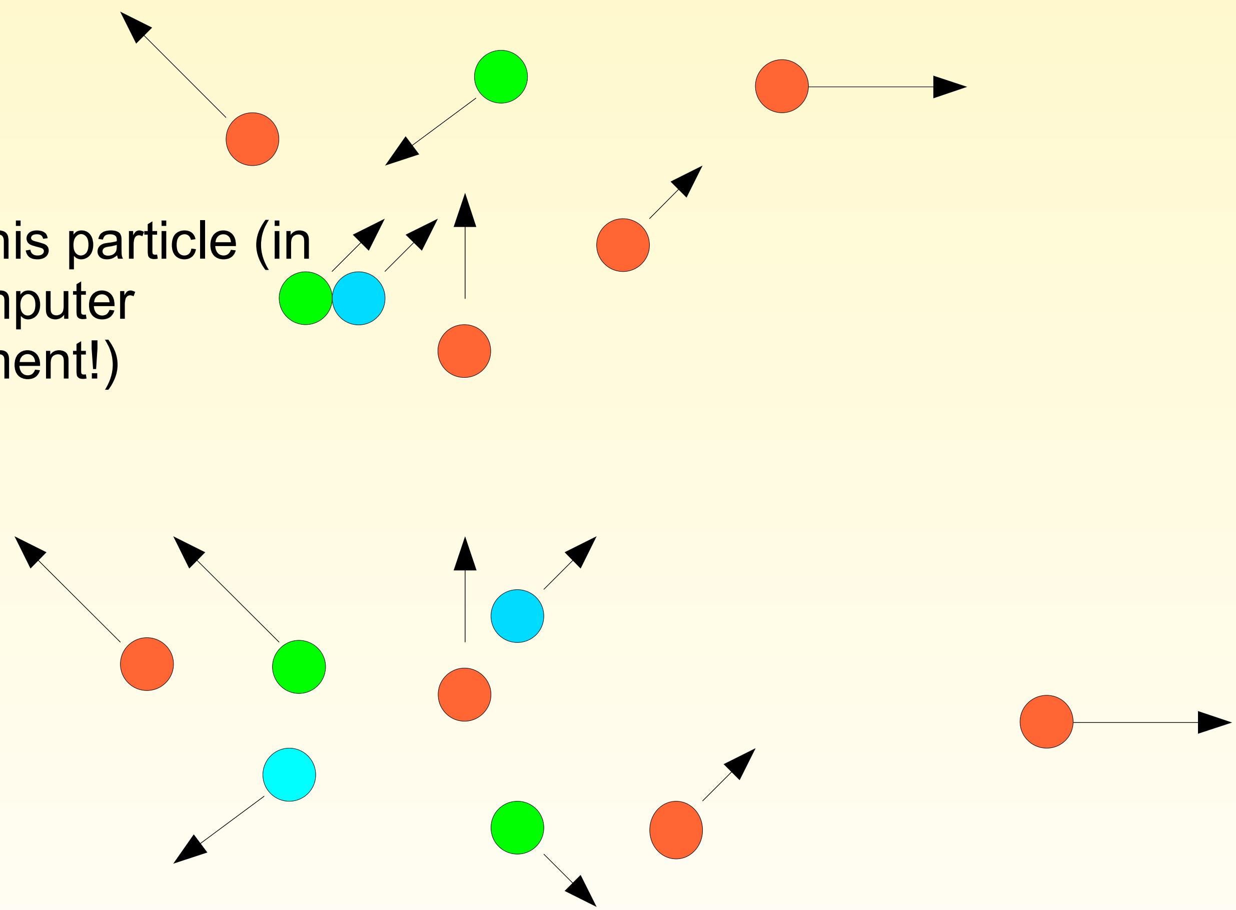
State at t6>t5

Why Reversing Velocities Doesn't Work

A small leak...

before the collision

move this particle (in the computer experiment!)



after the collision

...will sink a great ship!

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Example 2: Ferromagnetism

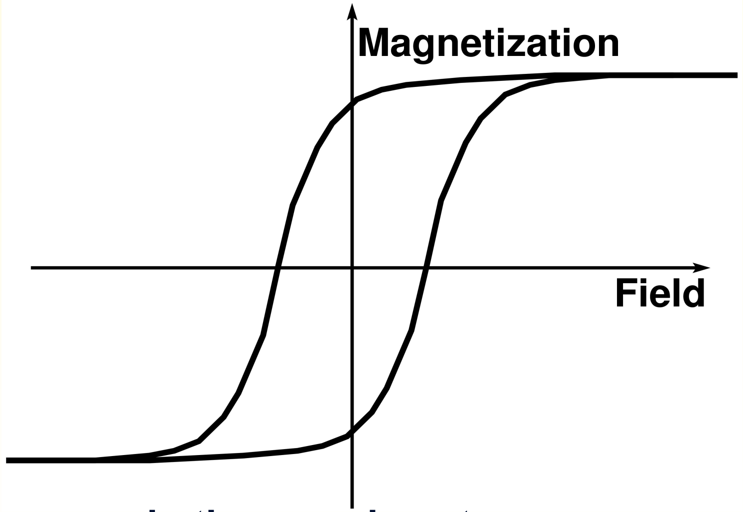
Ferromagnetism: the type of magnetic behaviour shown by iron, cobalt and nickel, which develop a strong magnetic field in the presence of an external field.

Magnetization: magnetic field generated by the sample itself as the response to an external magnetic field.

Magnetic Induction: sum of the external field and the magnetisation.

Hysteresis: the magnetization of the sample does not only depend on the external field, but also on the history of the process

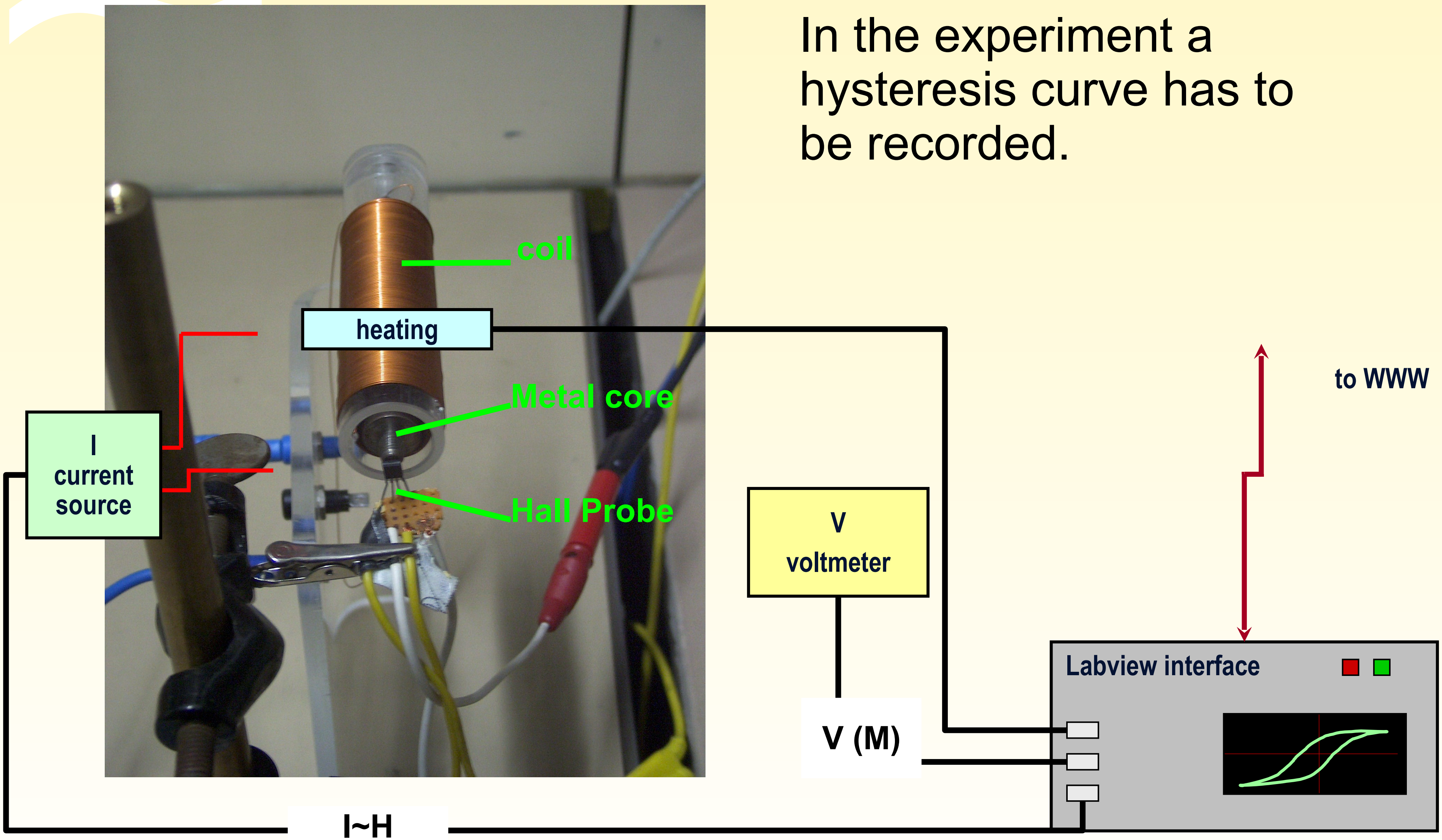
Ising Model: ferromagnetic media consist of elementary magnets that are either positively or negatively magnetized



in the experiment

The Remote Experiment: Hysteresis

In the experiment a hysteresis curve has to be recorded.

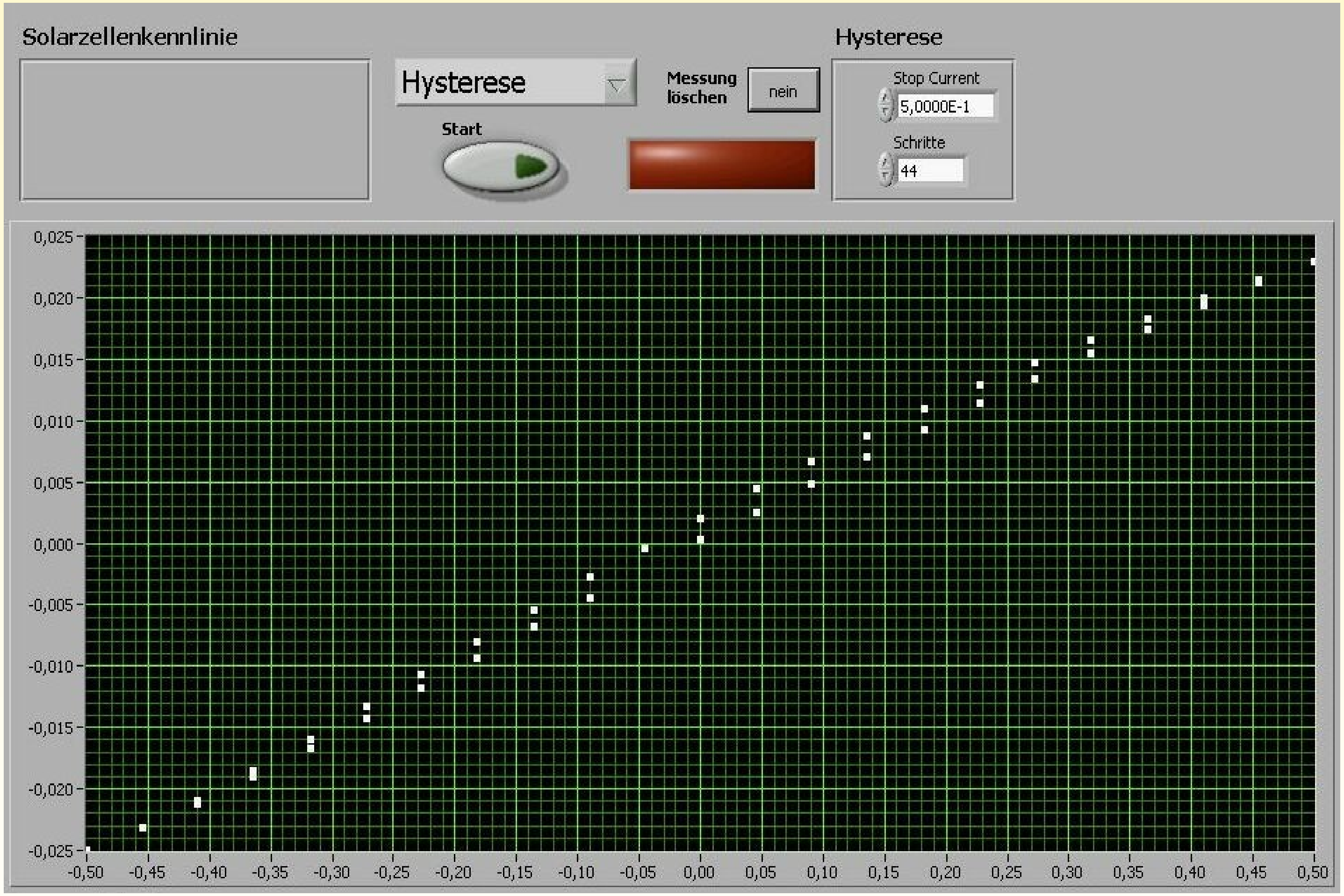


Students' View on the Remote Experiment

Hysteresis loop of a ferromagnetic material:

Magnetic induction over external field

LabView plugin, view in Browser



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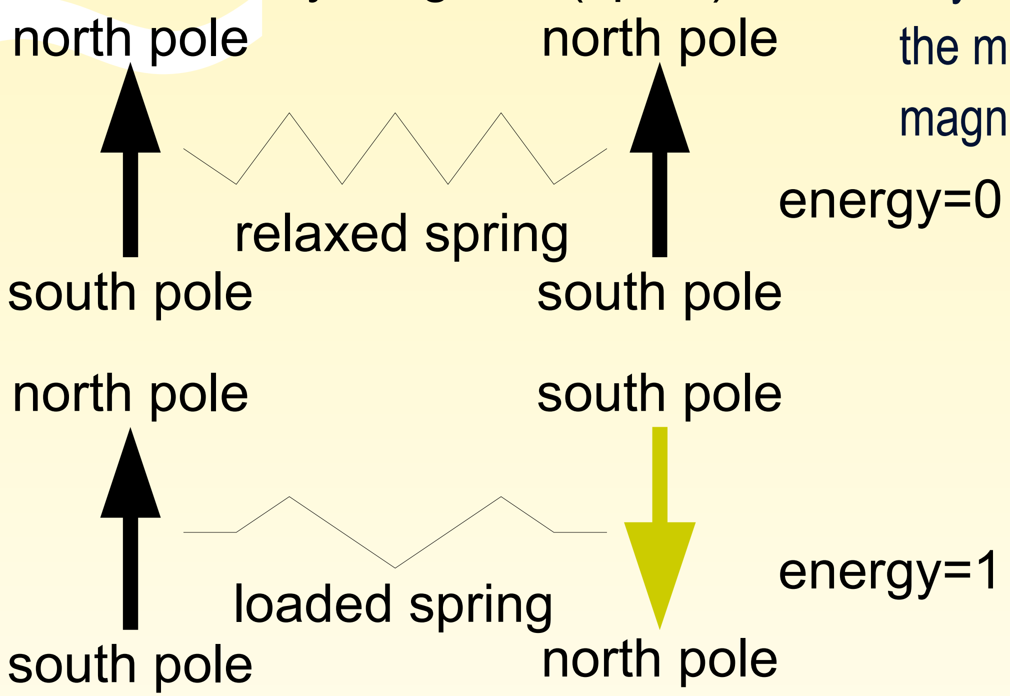
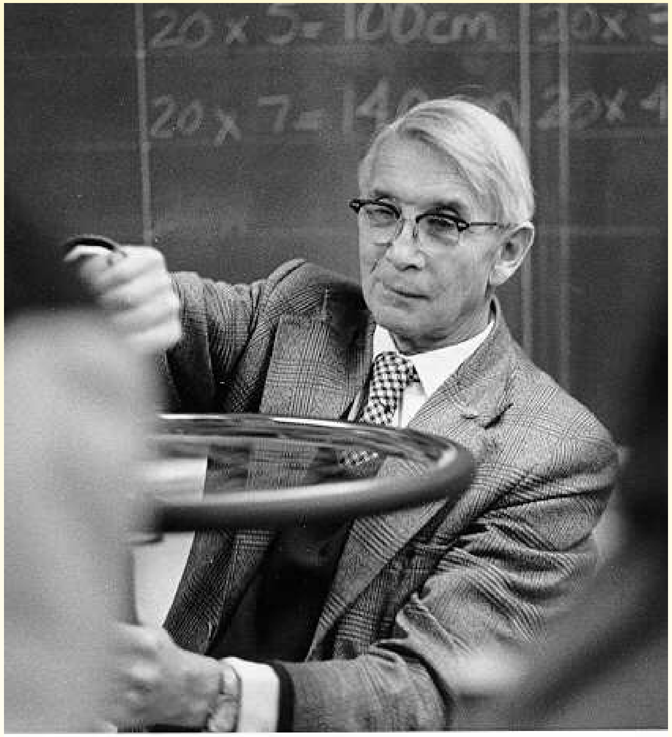
The Ising Model of Ferromagnetism

Elementary magnets (spins)



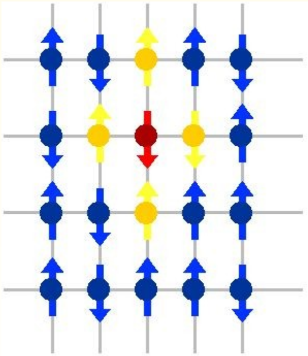
Toy model for statistical mechanics, the most prominent model to describe magnetic interactions (qualitative)



Ernst Ising, 1900 - 1998

Dynamics: reduce energy

Model in 2D: rectangular lattice, next-neighbor interaction between elementary magnets



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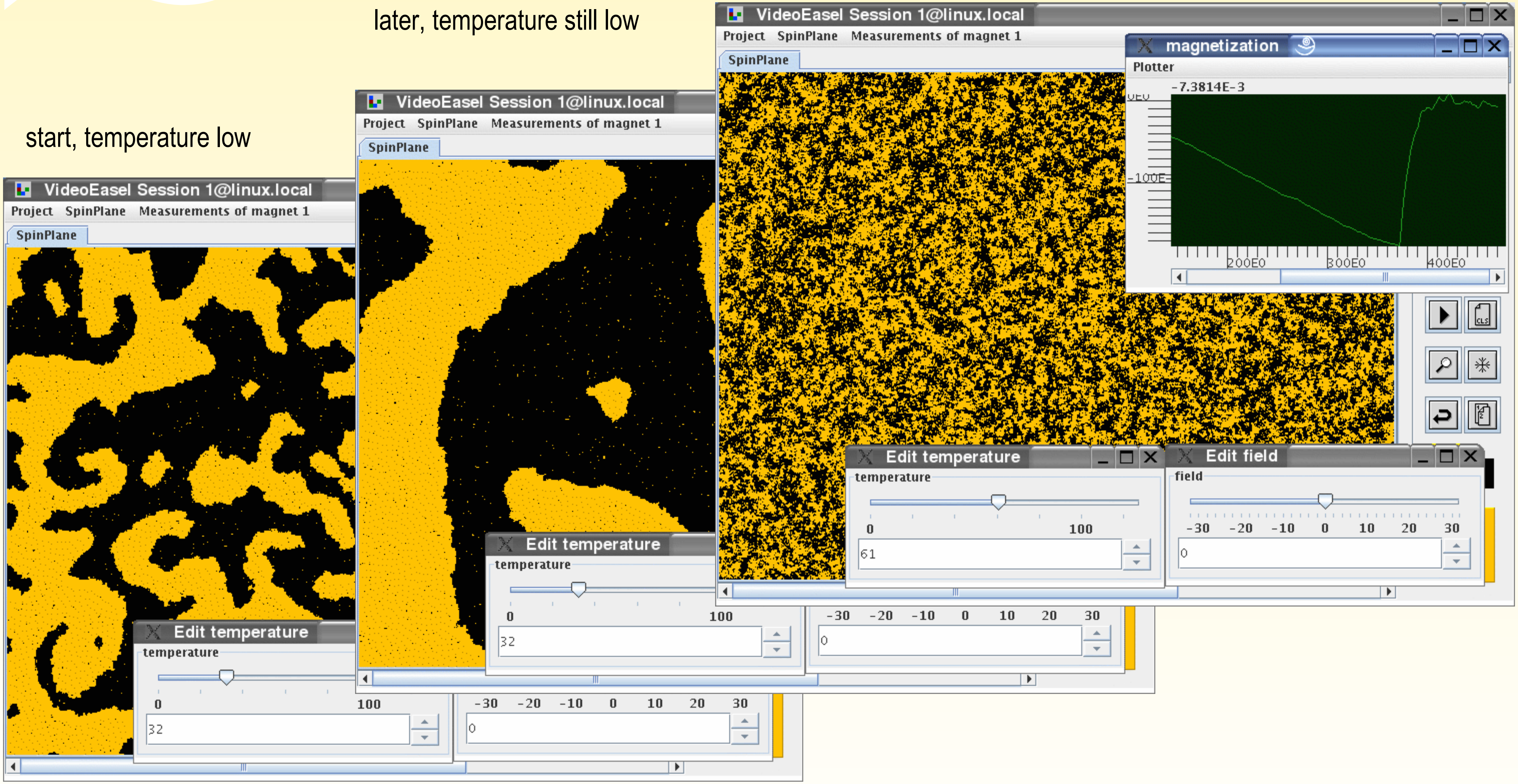
Spontaneous Magnetization

later, and temperature now significantly higher

later, temperature still low

start, temperature low



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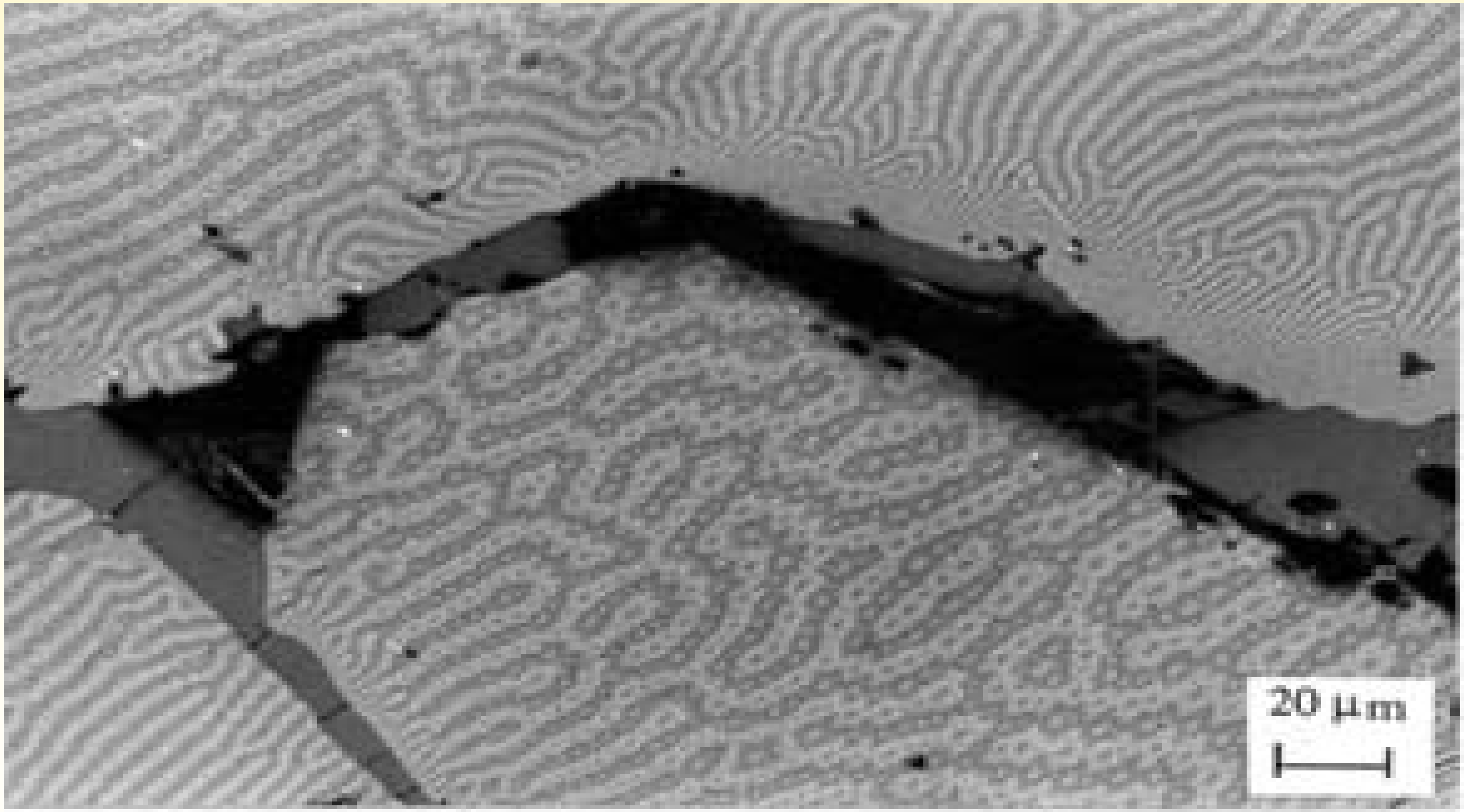
Weiss Domains in Reality

The rules of dynamics favour neighbourhoods of identically oriented elementary magnets, resulting in the zones of identical magnetization, called
Weiss-Domains.

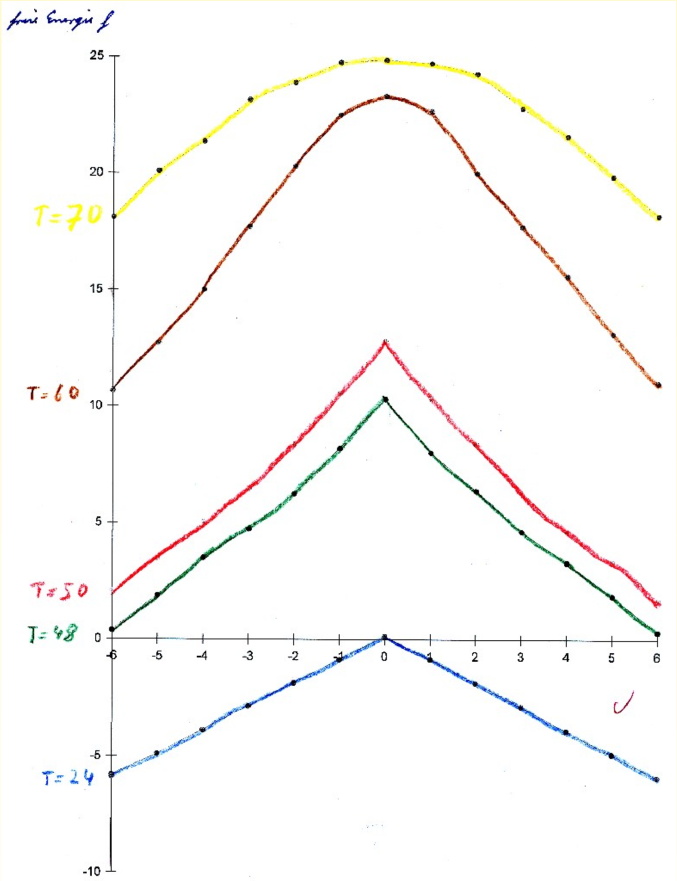


Weiss Domains, observed due to the Kerr-Effect.

Manual Measurements by Students

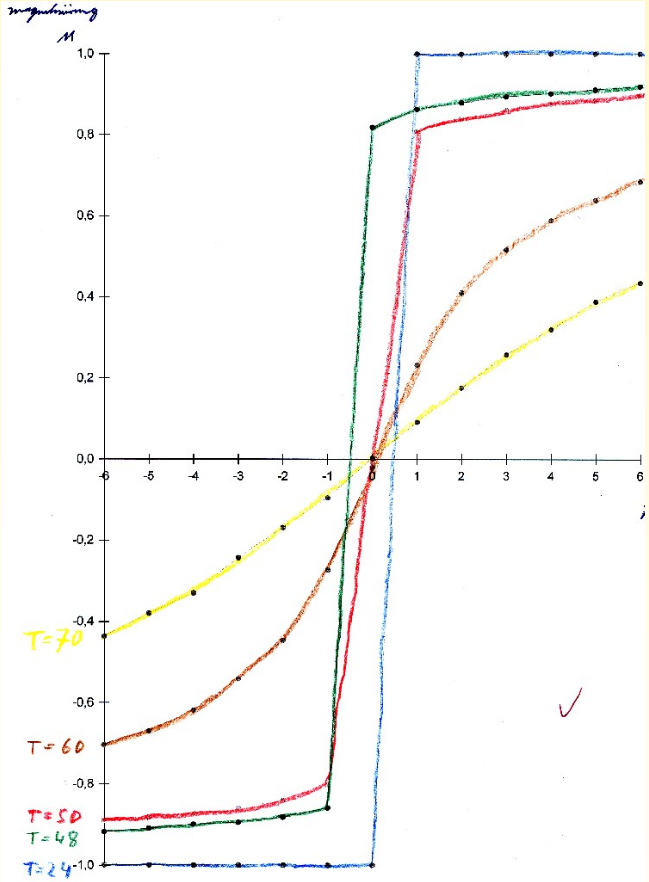
Helmholtz Free Energy f(h,T)

Energy available in the system for performing mechanical work



Magnetization m(h,T)

mean spin orientation



$$\Rightarrow m \sim \partial f / \partial h$$

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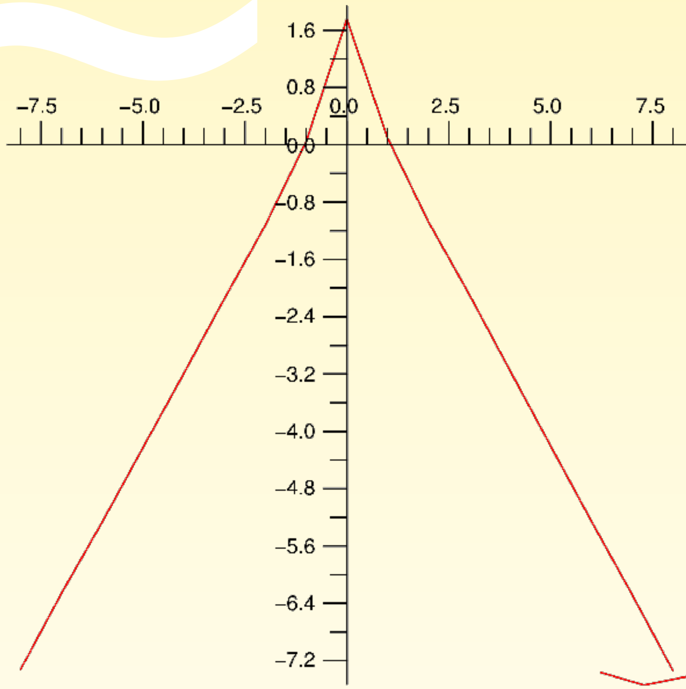
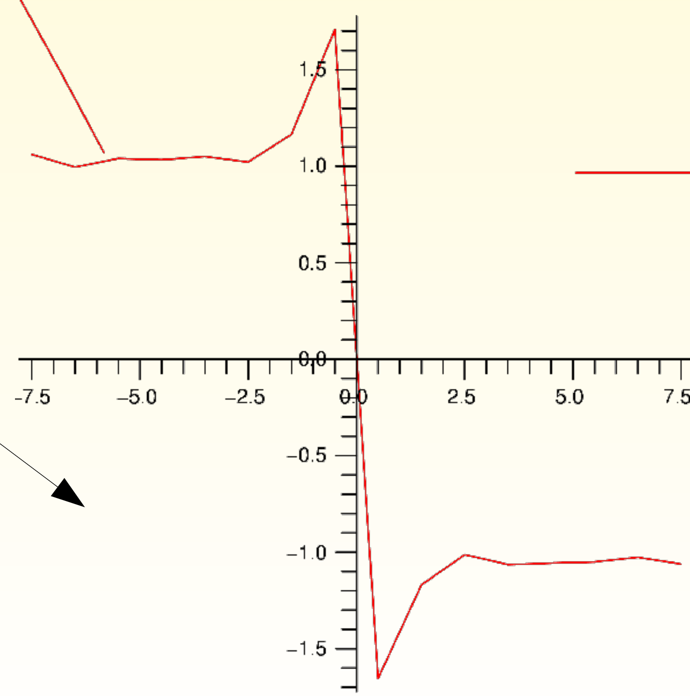
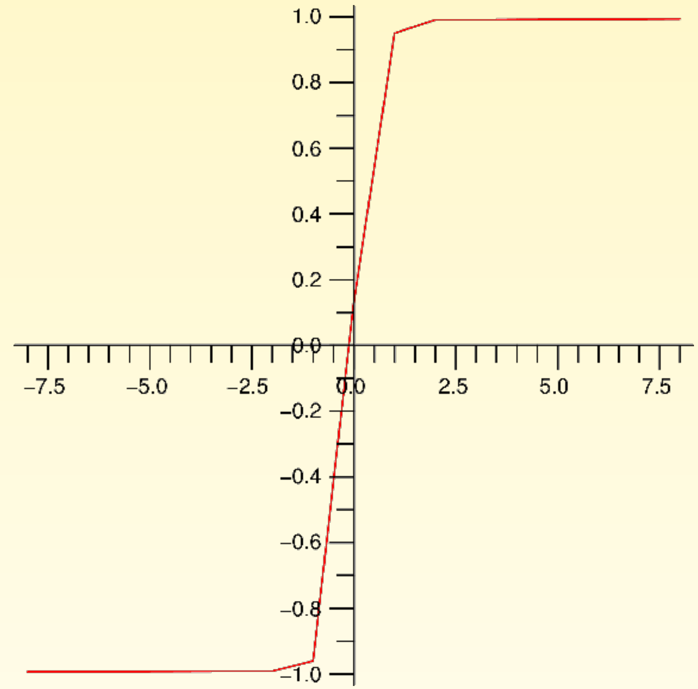
Numerical Results in Maple

Helmholtz Free Energy and Magnetization over the field



Numerical differentiation





Helmholtz Free Energy:

Energy available in mechanical work

∂/∂B

Magnetization:

mean spin orientation

Comparison:

m ~- ∂f/∂B

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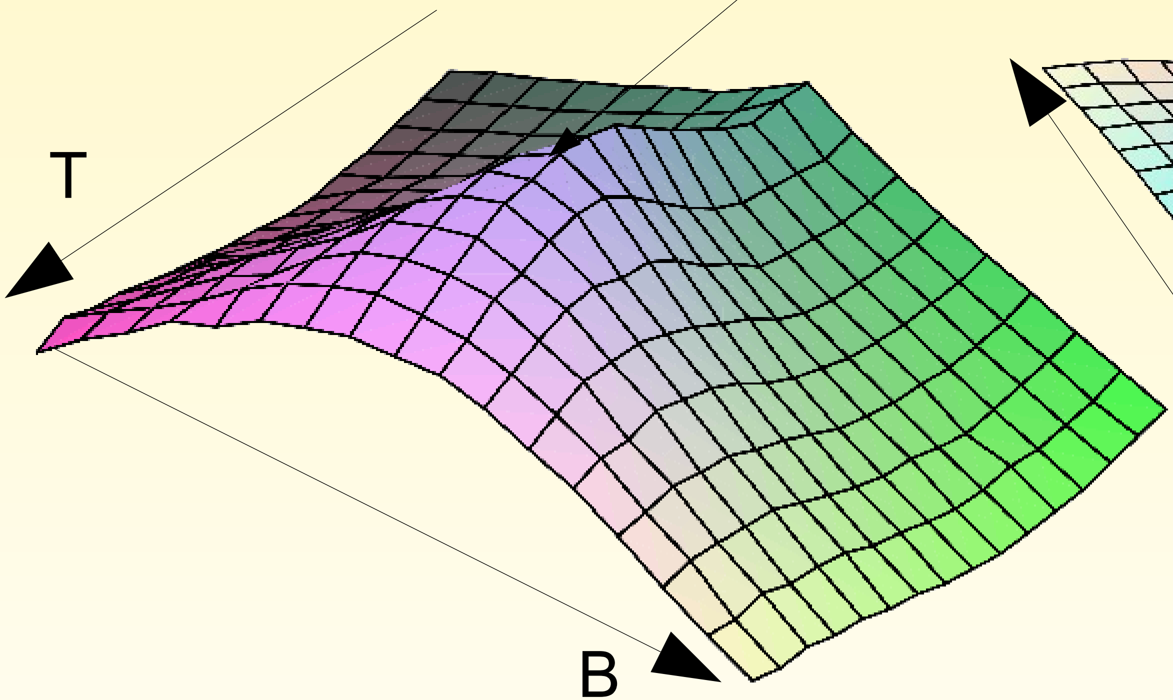
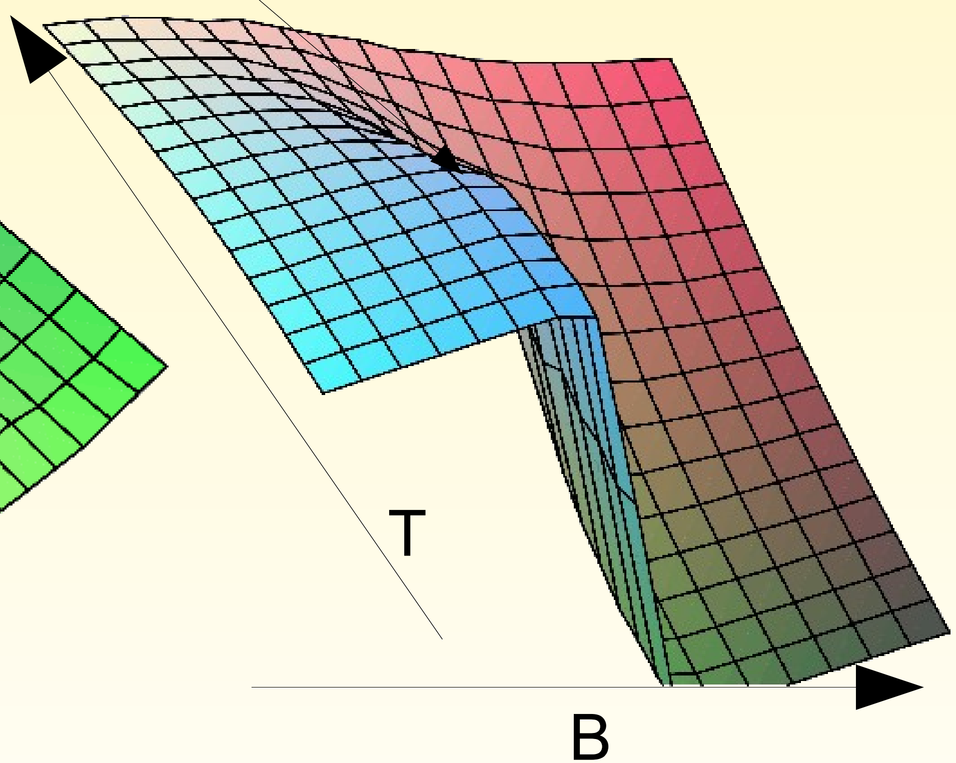
Numerical Results in Maple (2)

Phase transition $T = T_c$



Helmholtz Free Energy f(T,B)



Magnetization m(T,H)

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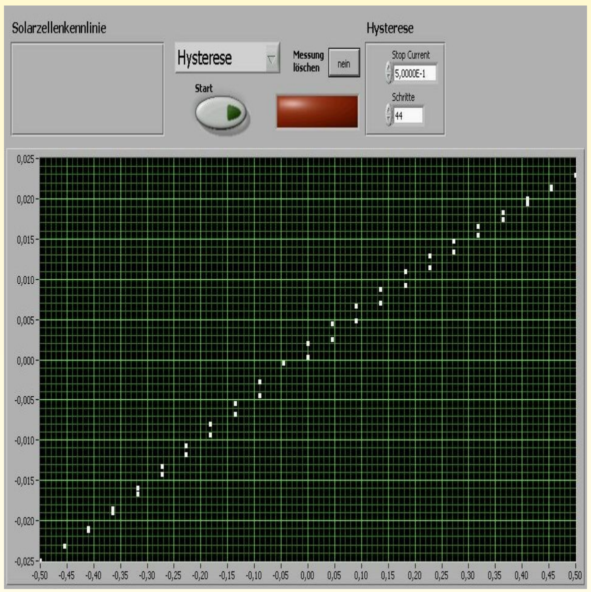
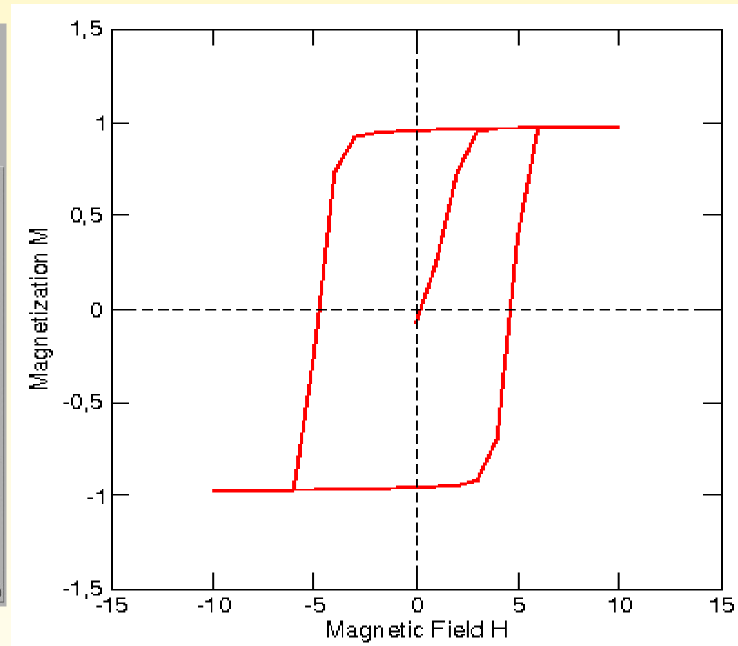
Discussion of the Results

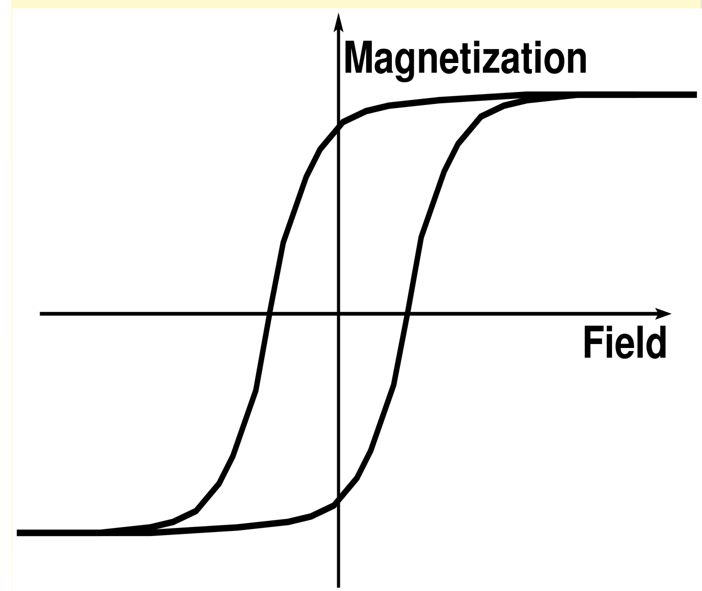
Measurements, Simulation and Literature **disagree**?



Measurement



Simulation



Literature

⇒ Models have a limited validity, theories make approximations, concepts must be stated precisely: Reality is predicted only within a certain error.

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Conclusions

- The roles of Remote Experiments and Virtual Laboratories differ:
  - Remote Experiments provide on-line access to real experiments
    - increased experimental capacity
    - simple evaluation of data
    - additonal experiments become available
  - Remote experiments address phenomenological aspects

  - Virtual Laboratories provide access to simulations
    - mathematical concepts become accessible
    - experiments impossible in reality can be studied

- The combination of Remote Experiments and Virtual Laboratories provides
  - attractive experiments to compare the theory with the measurement
  - to stress different aspects of a physical theory

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Outcome of the Virtual Experiment

•The Second Law of Thermodynamics makes a claim about the statistics of the system and holds for large systems and typical configurations.

• Loschmidt's objection holds, but a tiny distortion of the system completely destroys the backwards motion.

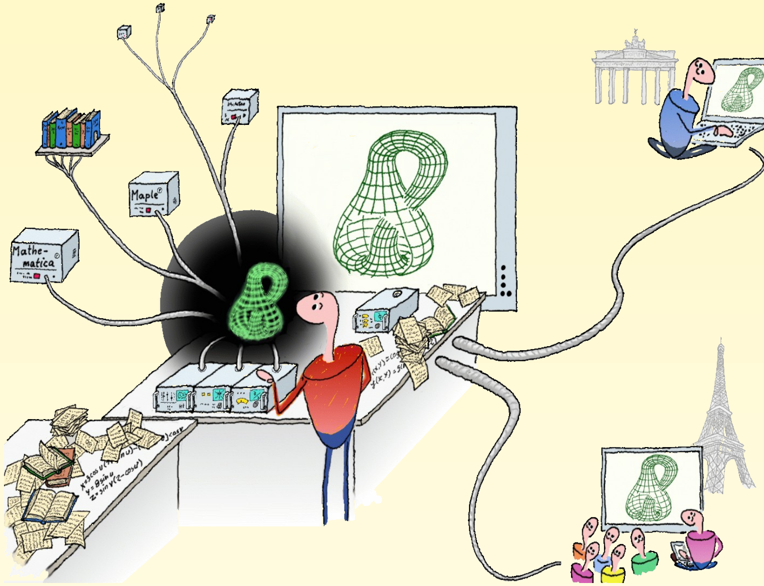
..and in General:

•Thermodynamics is both a **phenomenological** and a **statistical** science:

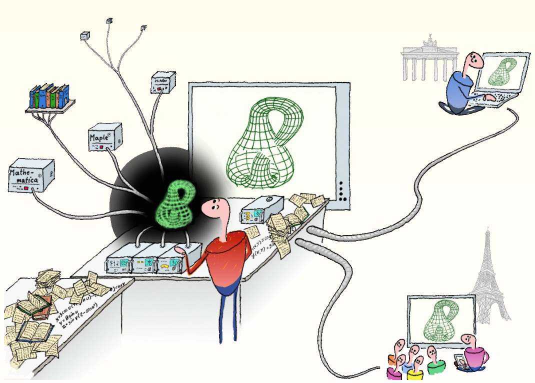
•The phenomenologcial side is addressed by Remote Experiments providing insight into the phenomenological definitions of the physical objects

•The statistical side is addressed by Virtual Laboratories providing mathematical experiments to address the abstract statistical definitions of the quantities

Part D



LiLa: The Project



Program Objectives

Objectives:

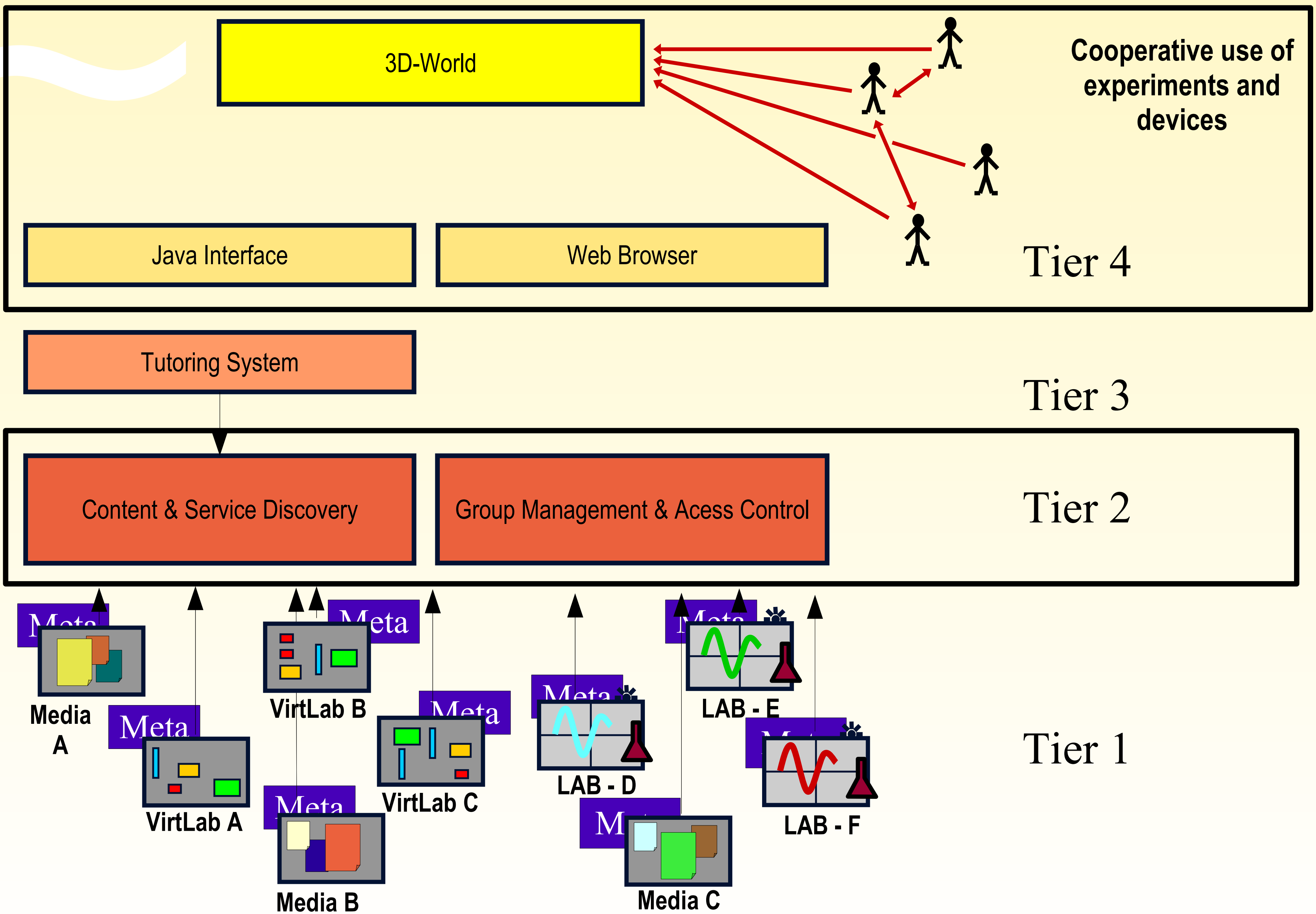
- create a repository of laboratories & media
- make them accessible by a retrieval system
- exploit them with an access control system
- provide a framework for online collaboration
- guide users with a tutoring system
- integrate labs into a virtual 3D world
- disseminate the network accross Europe, into curricula of universities

LiLa

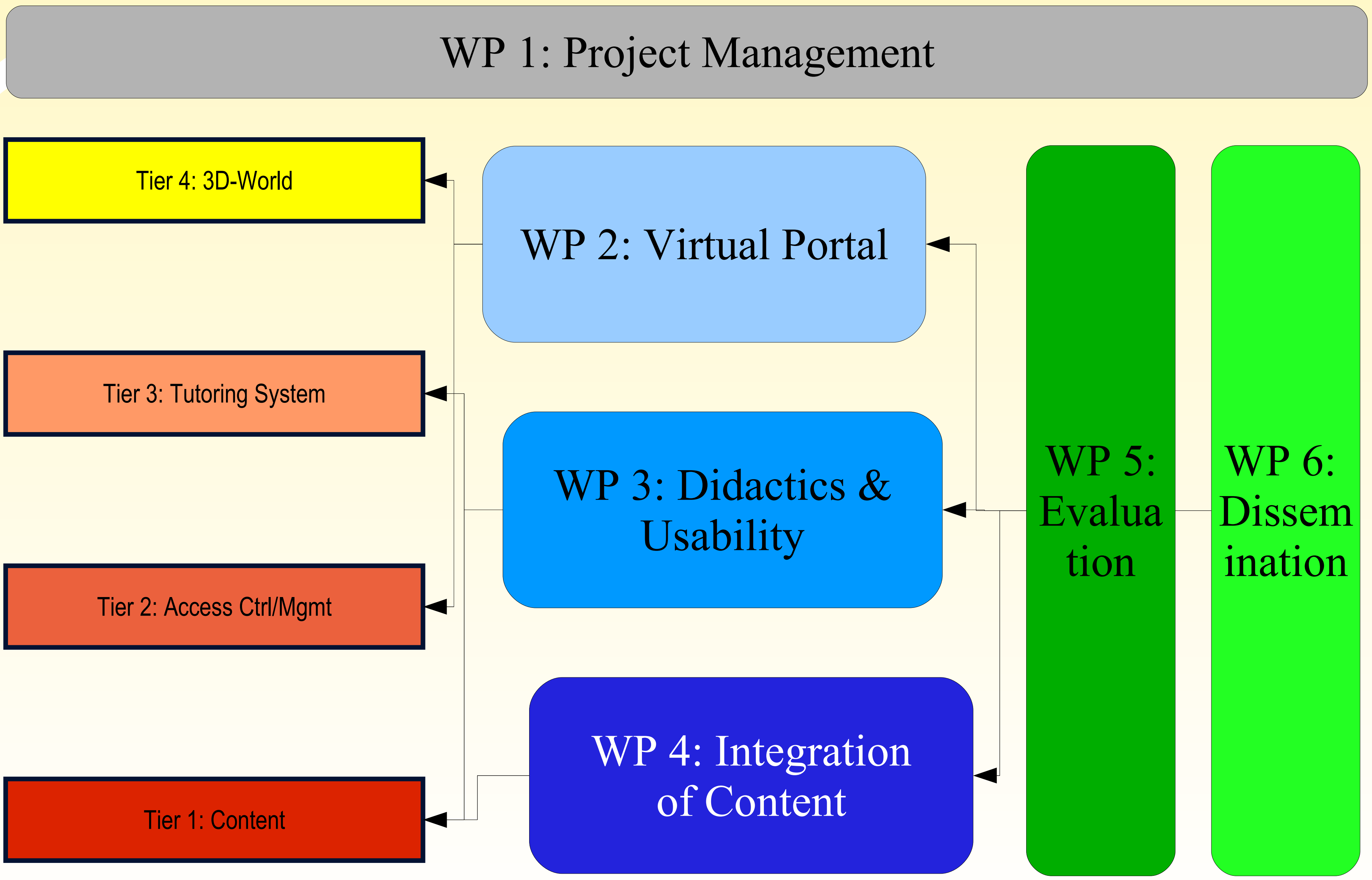
Demands on the Architecture

- LiLa is a „Content“ project, i.e. fokus is on making content accessible
- collect isolated solutions accross Europe in a network
- Provide a „link resolver“ for integrating and finding experiments in library catalogs
- develop solid access control and booking system for remote expriments
- add a „Tutoring System“ to support students in courses with the available materials (separate talk!)
- integrate remote experiments into a virtual 3D world („Wonderland“) to get some „grip“ on the experiments

Technical Architecture



Work Packages Overview



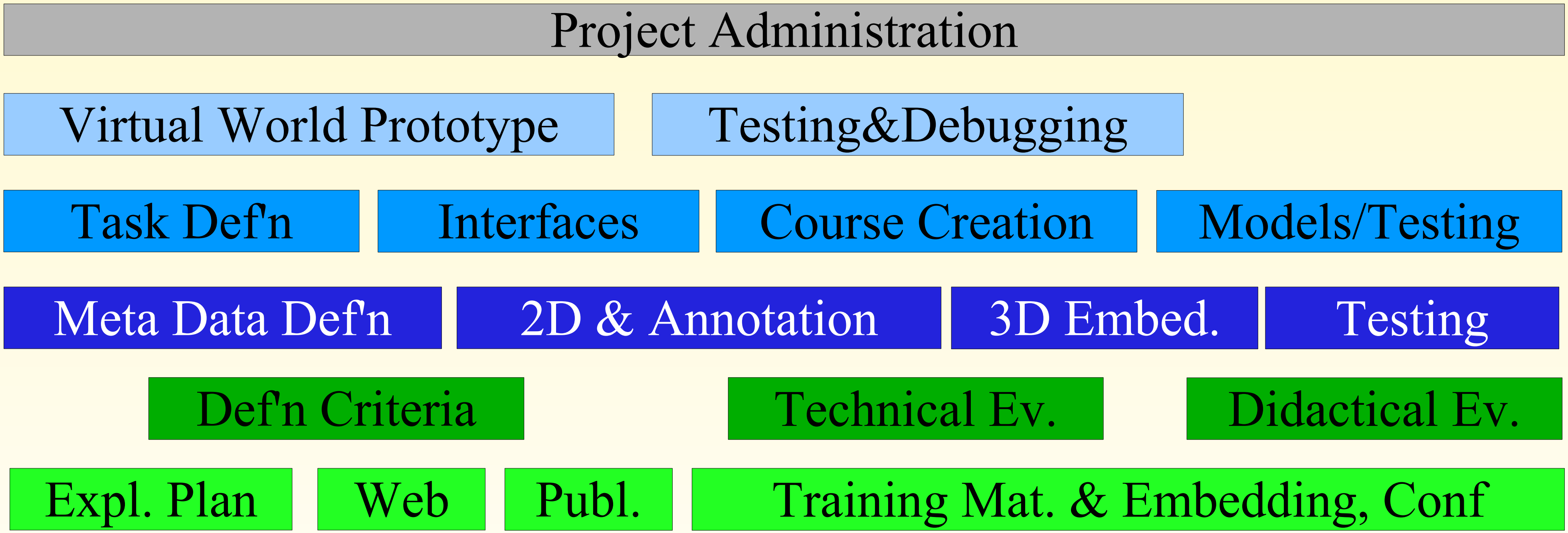
LiLa

Project Participants

Stuttgart	1	2	3	4		6
Berlin			3	4	5	6
Sun		2				6
Delft		2	3		5	6
Uni Linköping			3	4		6
MathCore		2	3			
Basel			3	4		
Madrid		2			5	6
Thessaloniki			3	4	5	6
Uni Cambridge			3	4		6
CMCL				4		6

Simplified Project Plan

for the complete Gantt-Chart, see the proposal



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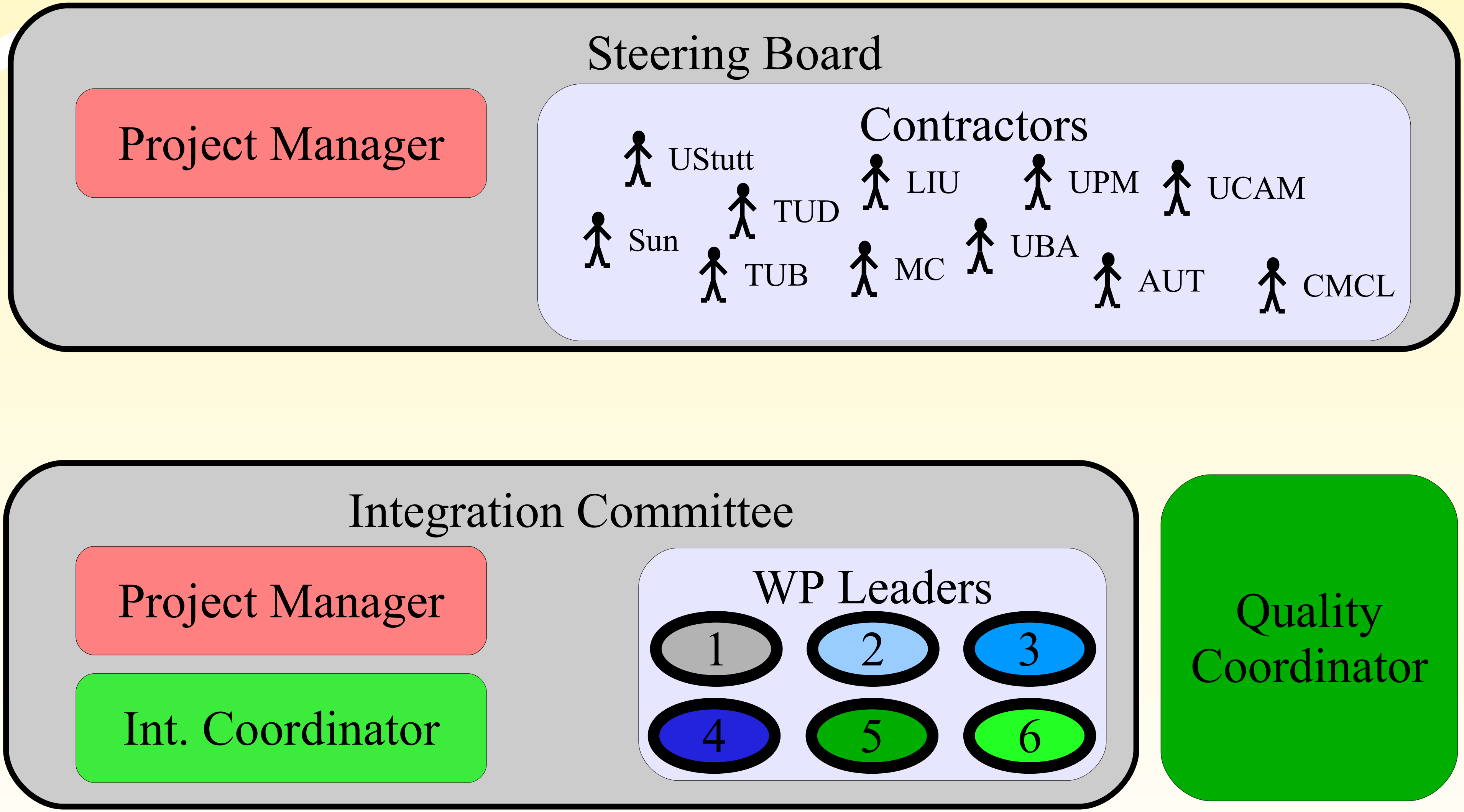
Management Structure



LiLa

The End

Sustainability of Virtual Labs and Remote Experiments has been demonstrated on a regional level:

- Lila extends this by disseminating our content to Europe.

Primary focus:

- Inter-disciplinary learning for students and teachers.