

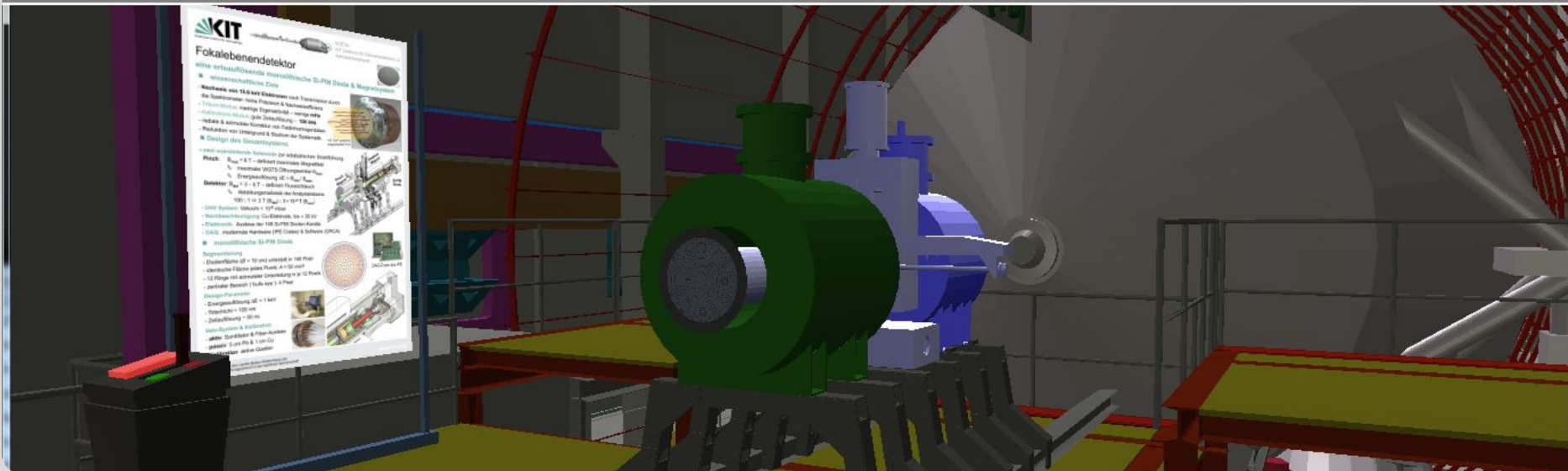
Virtual Reality Educational Games: a Case Study in Large Scale Particle Physics Research

An Educational Game for the KATRIN experiment

Till Bergmann

(Download-Link: <http://www.ipe.fzk.de/~bergmann/katringame/> or <http://www.tillbergmann.de/>)

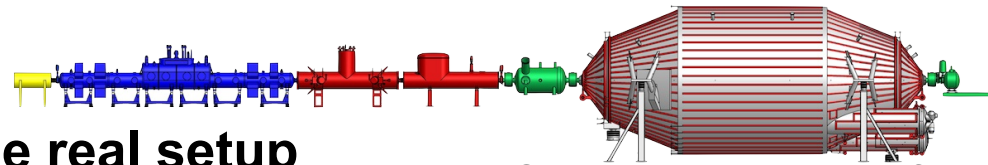
Institute for Data Processing and Electronics (IPE)



Virtual visits to large-scale physics experiments

Educational requirements

- illustrate the dimensions of the real setup
- all buildings and components explorable
- recognize virtual components in reality
- illustration of measurement principle (using animations, not: physics simulations)
- Interactive elements and game mechanics



Schematic drawing of experiment setup: size?



Spectrometer transport: this is large!

Implementation requirements

- look-and-feel of commercial adventure games
- affordable game design (time and money)
- use CAD drawings to construct the game geometry
- open source software (Blender, www.blender.org)

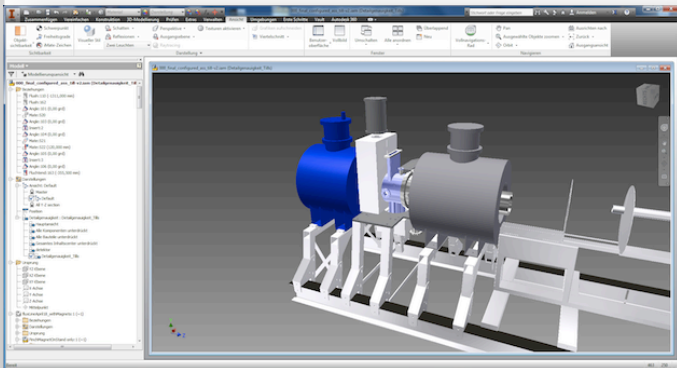


Under construction ...

From CAD drawings to the game geometry

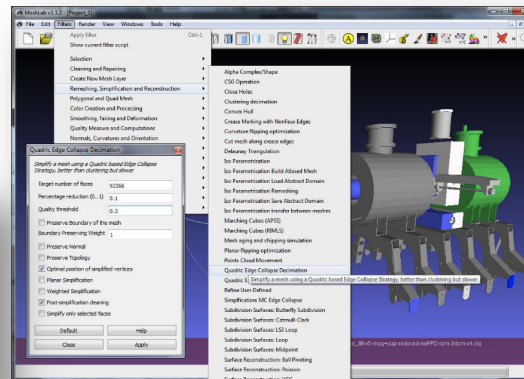
Workflow

- Inventor (AutoDesk™)
- MeshLab
- Blender 3D modeling



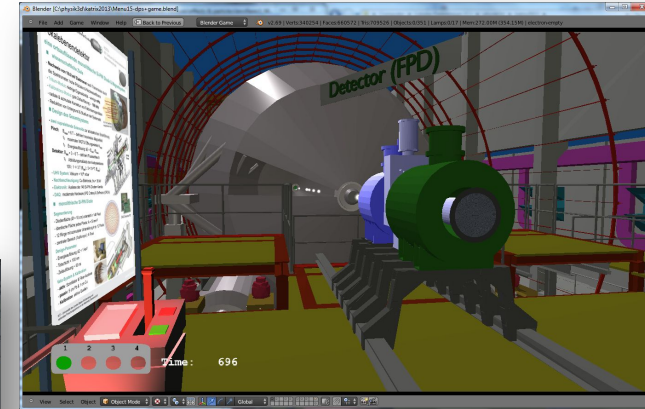
AutoDesk Inventor

1.000.000 polygons →
100.000 polygons



MeshLab

100.000 polygons

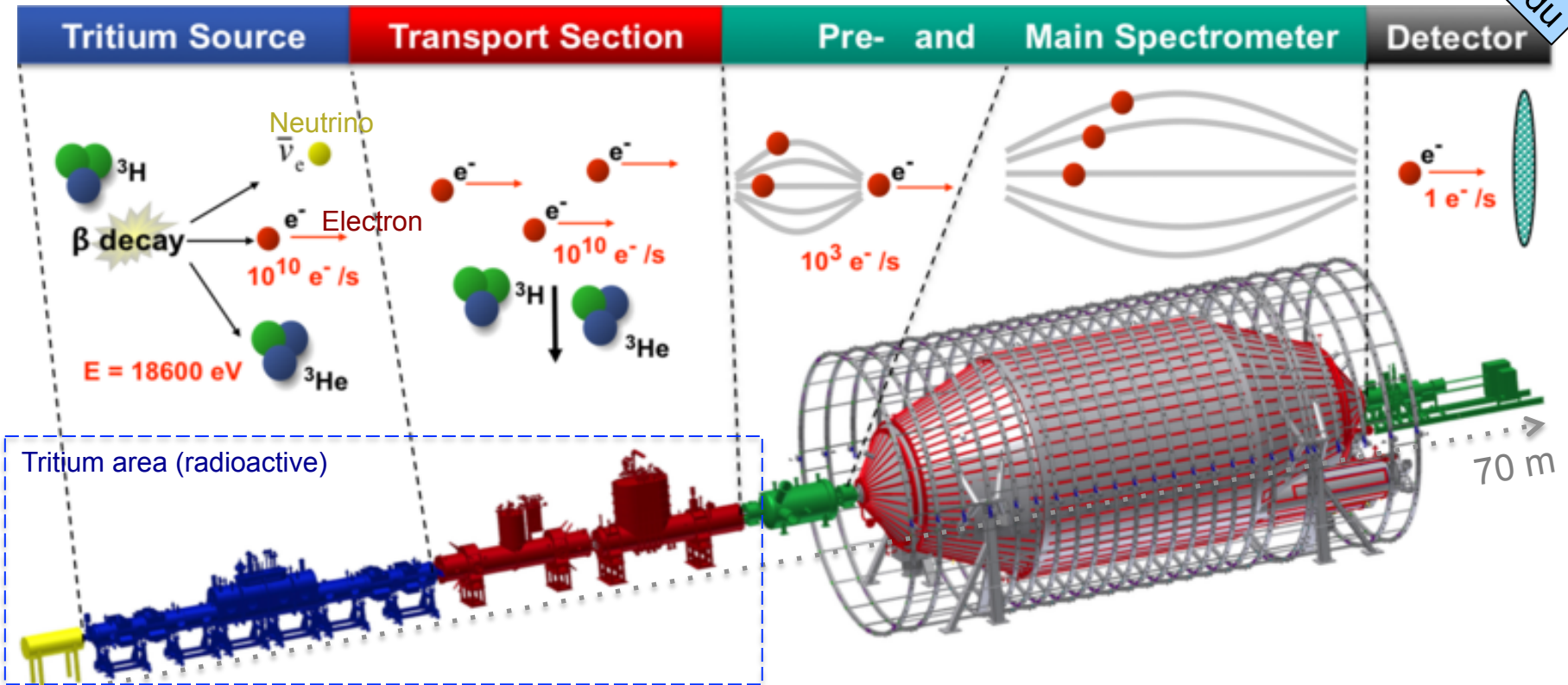
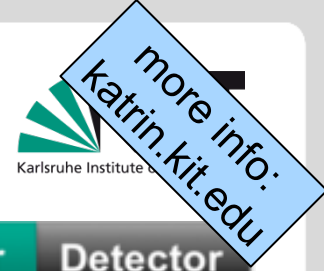


Blender

10.000 polygons
and finishing

**Fast game geometry
construction!**

The KATRIN experiment goal: direct measurement of the neutrino mass



Tritium decays, releasing an electron and an anti-electron-neutrino. While the neutrino escapes undetected, the electron starts its journey to the detector.

Electrons are guided towards the spectrometer by magnetic fields. Tritium has to be pumped out to provide tritium free spectrometers.

The electron energy is analyzed by applying an electrostatic retarding potential. Electrons are only transmitted if their kinetic energy is sufficiently high.

At the end of their journey, the electrons are counted at the detector. Their rate varies with the spectrometer potential and hence gives an integrated β -spectrum.

KATRIN educational game: features

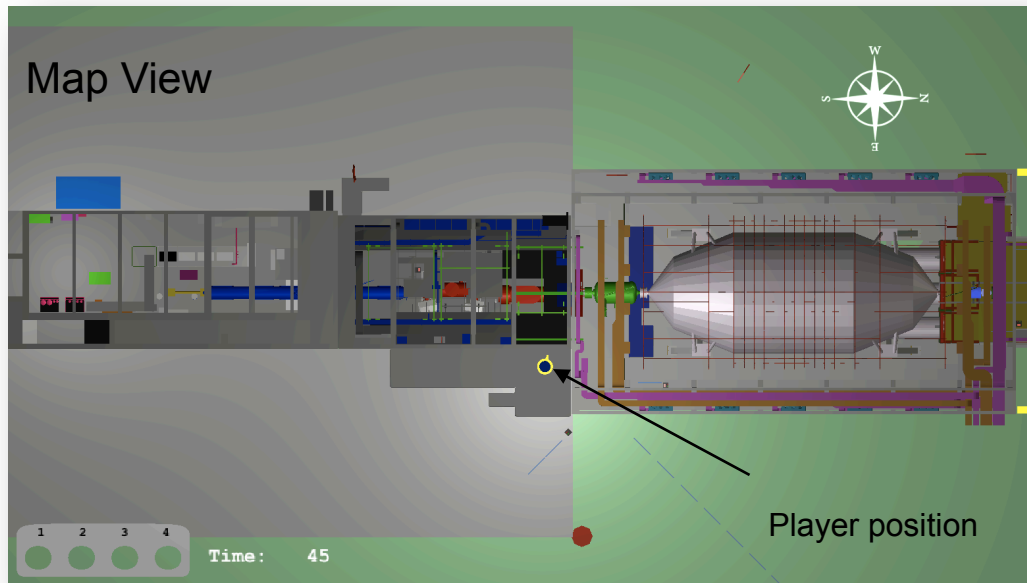
- Game navigation: standard WASD control scheme
- Virtual posters: copy of real posters and game instructions



Virtual posters: info points (physics and technics) and game instructions

KATRIN educational game: features

- virtual tour marked with red arrows
- map view to keep orientation
- user interaction (switches) → animations



Arrows mark virtual tour

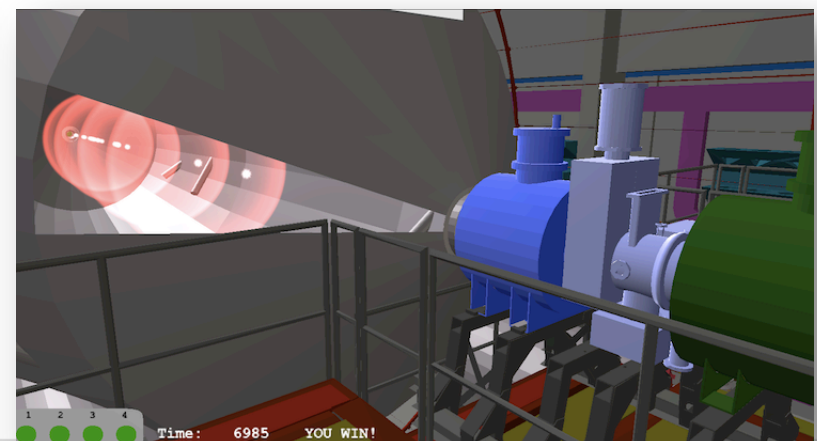
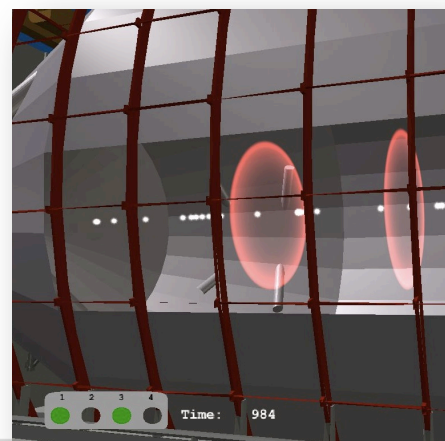
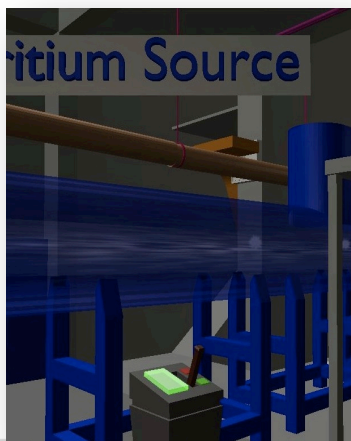
- X-Ray view to see interior of components



Switch

Animations illustrate the measurement principle

- Tritium source: Tritium gas flow and electron production
- Main spectrometer
 - visualization of force on electrons induced by retarding static E-field
 - retardation and acceleration of electrons
- Detector:
 - move detector carriage towards main spectrometer
 - dock to main spectrometer
- Game puzzle: activate all switches in the correct order!



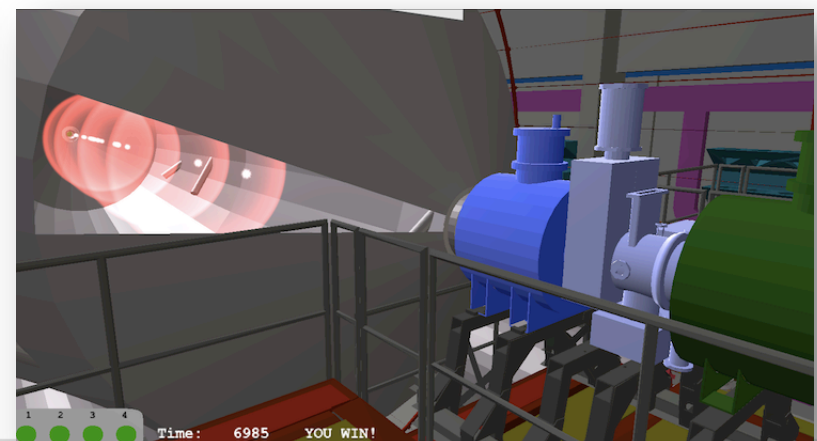
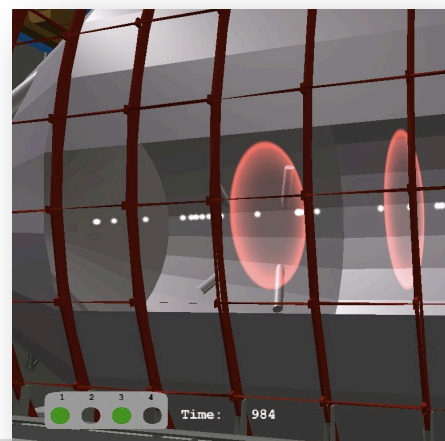
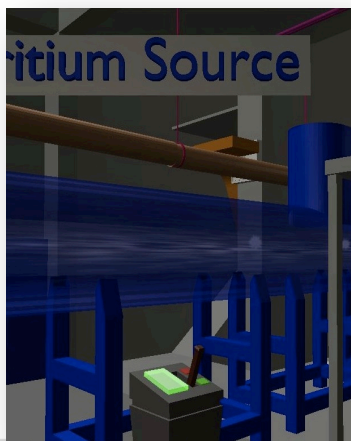
Animations – Video: Tritium Source + Transport section

- Tritium Source + Transport section
- Main Spectrometer + Detector

**PDF-Version!
Videos are not
included in this
version!**

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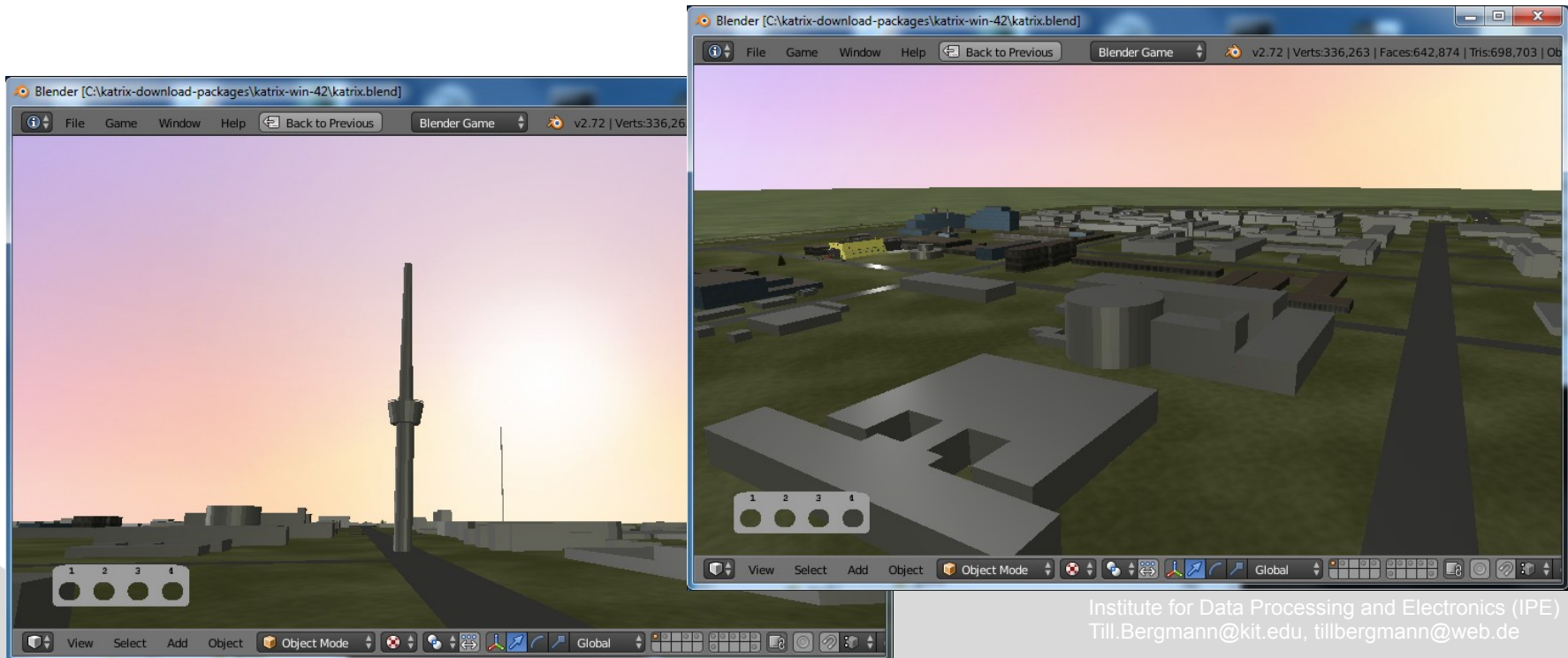
Animations – Video: Main Spectrometer + Detector

- Tritium Source + Transport section
- Main Spectrometer + Detector

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KIT campus site with 'easter egg'

- KIT campus: may help visitors to find KATRIN
- Possible extension: show other experiments
- Easter egg = beam up on tower: satisfy play instinct



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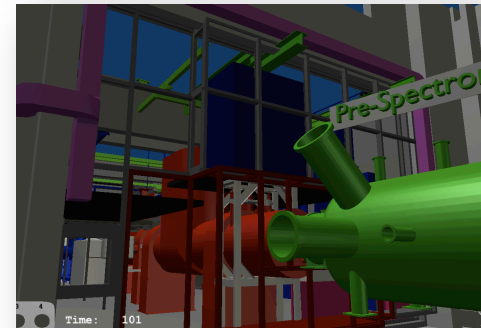
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Use cases of the educational game

- visit final assembly of the experiment: follow red arrows
 - possible, even if not yet assembled in reality!
- visit closed/restricted areas
- visualize invisible (and dangerous) processes
- get a visual impression of the measurement principle and the interplay of the main experiment components: solve the game puzzle
- for physics students: learn details and background about KATRIN:
 - follow the virtual tour (red arrows)
 - read the posters about physics
 - solve the game puzzle
- training for experiment operators from distant countries (PhD/Diploma students)



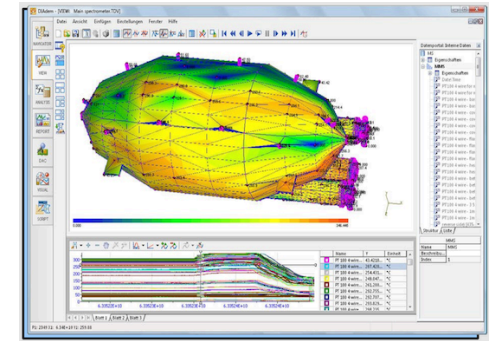
Under construction ...



Same view in game

Outlook

- Sound
- Physics simulation visualization
- Slow control data visualization for operators
- better interaction and tour planning for teachers



Slow Control Data with Diadem

Nowadays we have great tools to build computer games: we have powerful 3D graphic cards and great software – even open source!

Use gamification as visualization tool!

Visualization is the fundamental of all knowledge.

(freely adapted from Johann Heinrich Pestalozzi, 1746 – 1827)

The game is the way that children get to know the world in which they live (and which they are called upon to change). (Maxim Gorky, 1868 – 1936)

Backup Slides

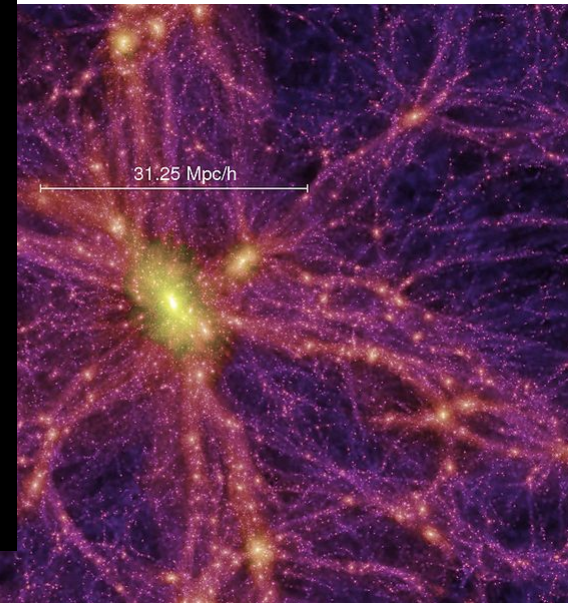
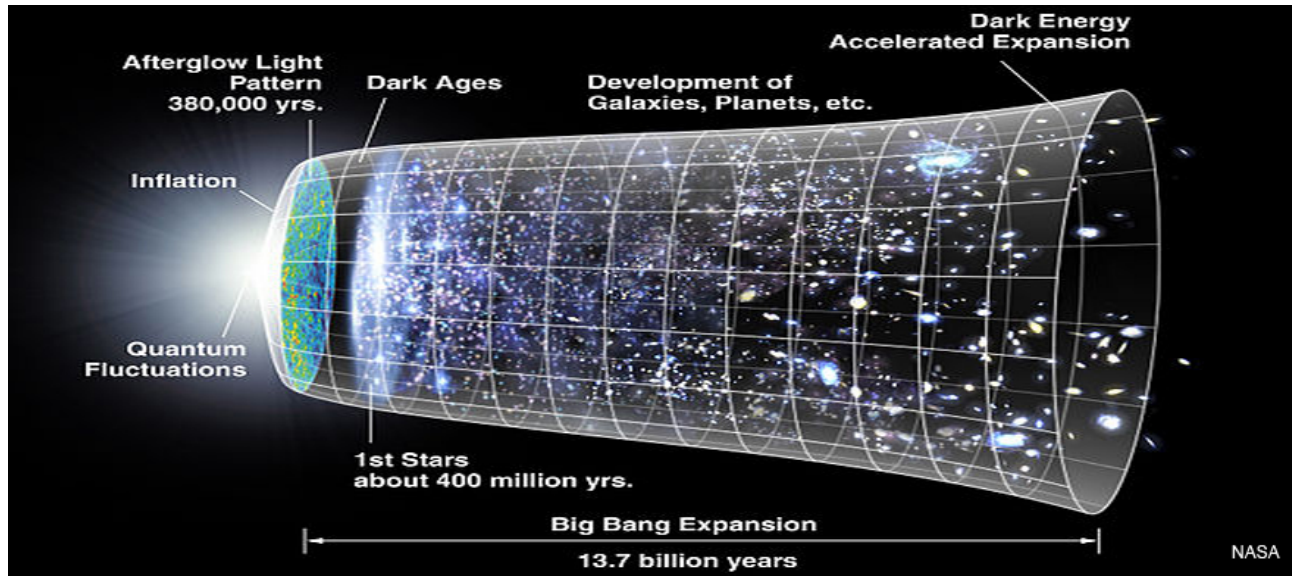
- Neutrino Physics
- WASD game control scheme
- Tested Hardware
- Blender
- Learning Pyramid

Physics and measurement principle



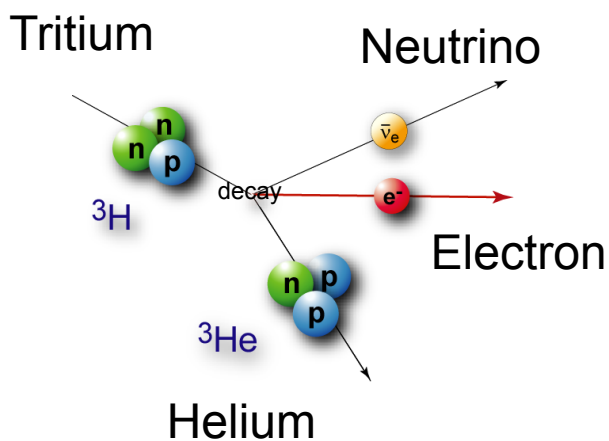
Neutrino Physics

- observation of neutrino oscillations → neutrinos have mass
- most important open issue in neutrino physics:
 - *What is the absolute mass scale of neutrinos?*
- most abundant particle with mass in the universe
- → considerable influence on the development of the universe
- recent experiments: neutrino mass smaller than $2 \text{ eV}/c^2$
- (electron: $511000 \text{ eV}/c^2$, KATRIN sensitivity: $0.2 \text{ eV}/c^2$)

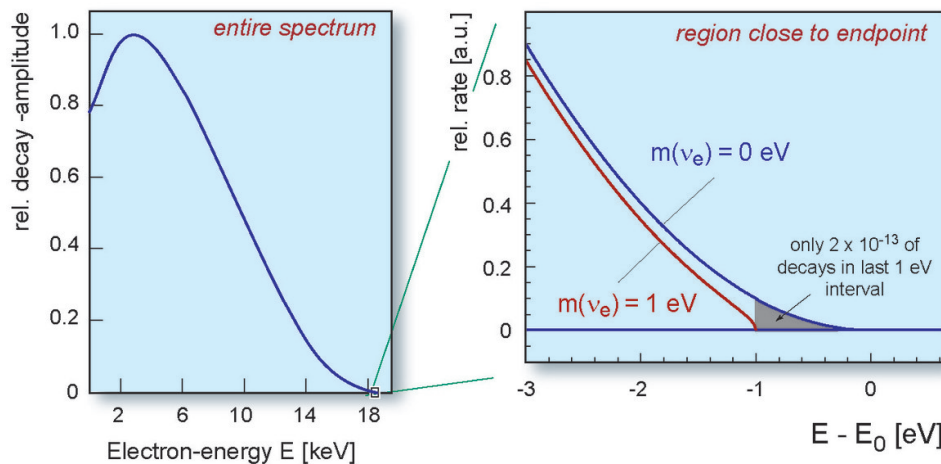


Measurement principle: Tritium decay

- released energy $E_0 = 18600$ eV, shared between kinetic energy of electron and neutrino
- the neutrino vanishes \rightarrow measure energy E of electrons to get information about the $m(\nu_e)$
- the maximum possible electron energy E is $E_0 - m(\nu_e)$



Tritium Decay



Electron Energy Spectrum

- navigation: WASD control scheme

•Virtual posters:

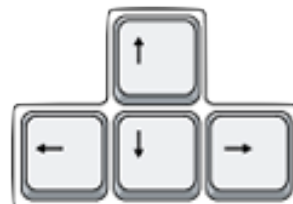


originates from
T-shaped arrow
key block

Combination of
keyboard and mouse:
Walking: WASD-keys
Viewing direction:
Mouse move

Walking

W: forward



A: left

D: right

S: backward

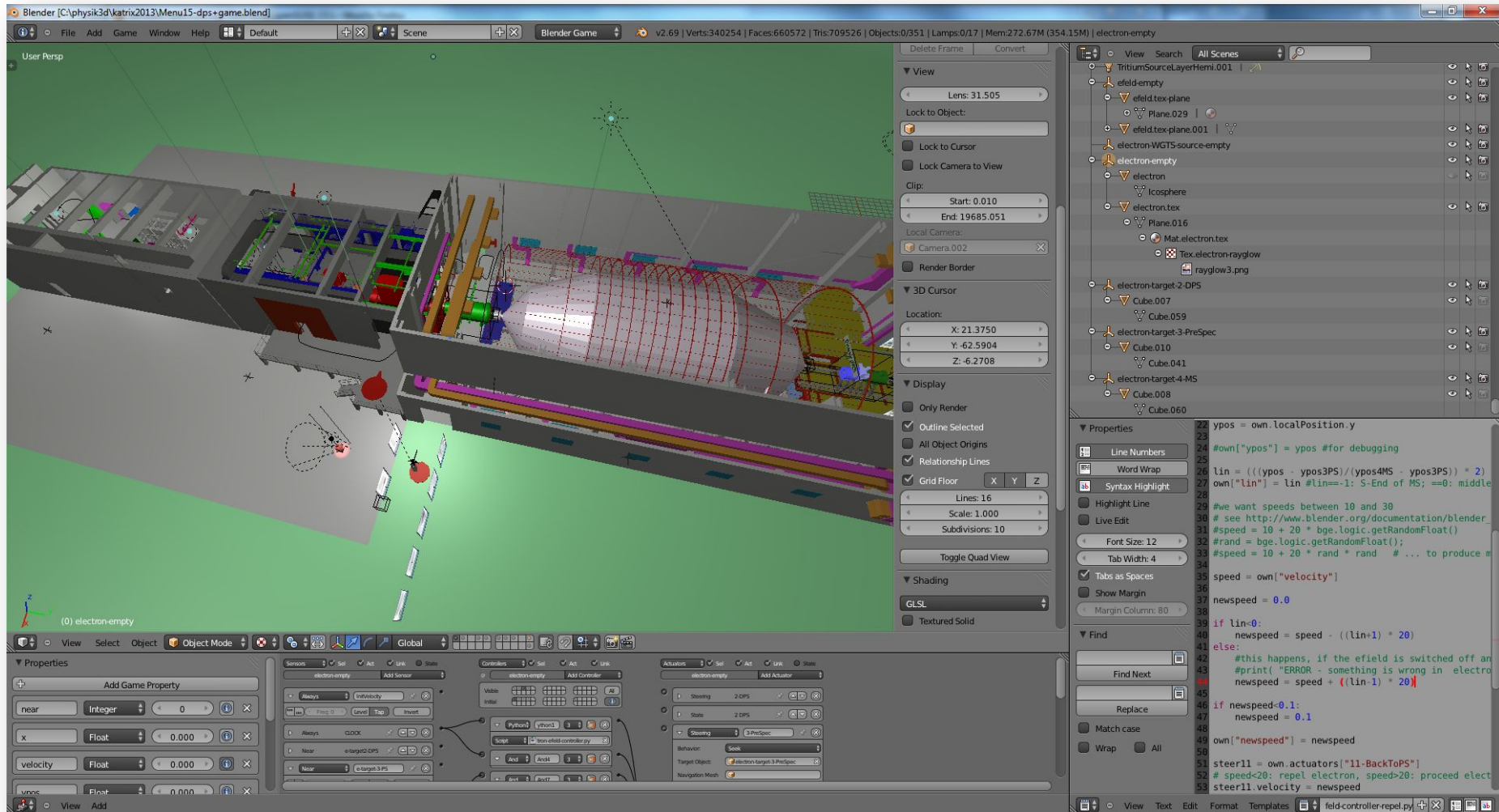
Viewing direction



Table 1: Performance (frame rate) of several systems (operating system, CPU, graphic card)

<i>System</i>	<i>OS</i>	<i>CPU</i>	<i>Graphic card</i>	<i>frames/second</i>
Desktop PC	Windows 7	AMD Phenom II X4	GTX 295 Quadro 600	60 (excellent) 10-30 (acceptable)
Desktop PC	Windows 7	Intel i7-950 (3 GHz)	GTX 680	60 (excellent)
Notebook	Windows 8	Intel 2020M (2.4 GHz)	NVidia 610m	40-60 (very good)
MacPro 2009	OSX 10.6.8	Quad-Core Xeon	Quadro 4000	60 *
MacMini 2012	OSX 10.8.2	Core i-5 (2.5 GHz)	Intel HD 4000	60 (excellent)
MacBook	OSX 10.6.8	Core 2 Duo (2.5 GHz)	NVidia 8600M GT	7-18 *
MacBook	OSX 10.8.2	Core i-5 (2.4 GHz)	NVidia GT 330M	3-30 *

*On Mac OSX performance was measured in the embedded Blender player, Blender in full screen; for all other tests the standalone Blender player in full screen was used.

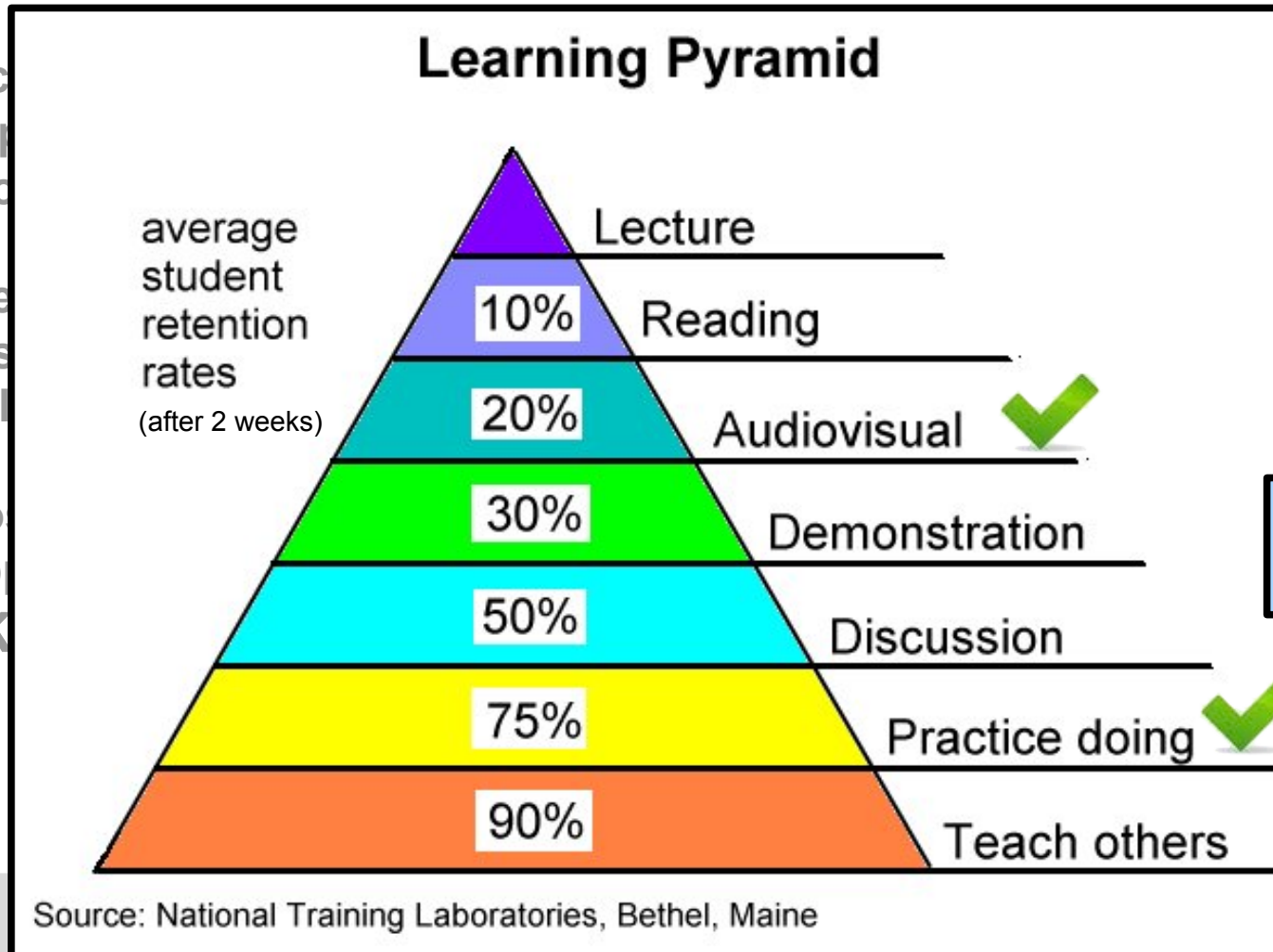


Physics Education:
excursions important for sensual and visual experience beyond theoretical and scientific lessons
→ supports sustainable comprehension

Public
great p
→ pro

Proble
•access
•travel

Propo
VR ap
the K



Game