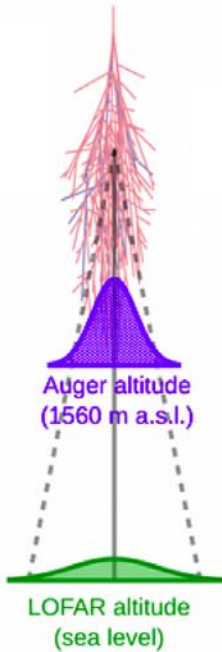


Advances in Detection Techniques

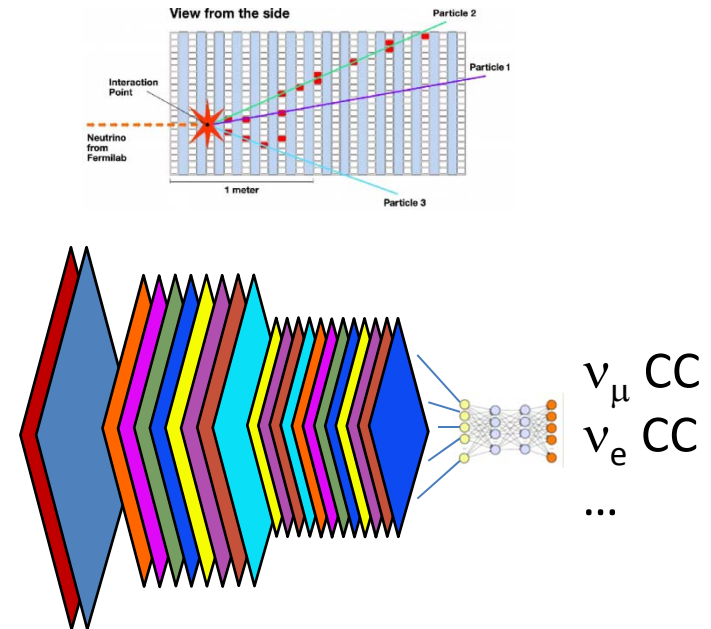
Instrumentation - Calibration - Monitoring



Cosmic ray 1 EeV

MHz: 15.8 MeV

Deep Learning



HAP Technology Workshops!

Helmholtz Alliance for Astroparticle Physics

Advanced Technologies Workshop
Topic 4 - Kick Off Meeting

Program:

- In-air radio detection
- Microwave detection of high-energy cosmic rays
- In-matter detection of high-energy neutrinos
- Cherenkov array for air showers and high-energy gamma rays
- Advancements of PMT development
- Multi-channel read-out systems
- Air shower observations from space
- Lower energy extension of IceCube
- Design of a readout system for EURECA
- Digitizing analog signals at high sampling rate and bandwidth
- Development of intelligent triggers, digital data processing and event building
- Design of low-noise, low-power preamplifier
- Calibration of large liquid Xenon detectors
- Calibration methods for novel low-temperature light detectors

Scientific coordination: Matthias Kiefgasse
matthias.kiefgasse@kit.edu

Administrative contact: Christiane Buchwald
christiane.buchwald@kit.edu

FTU, Karlsruhe Institute of Technology
January 24-25, 2013

<http://indico.aicc.kit.edu/indico/event/hap-topic4-workshop>

KIT
HELMHOLTZ ASSOCIATION
Alliance for Astroparticle Physics

www.hap-astroparticle.org

2013

Helmholtz Alliance for Astroparticle Physics

Detector Design and Technology
for Next Generation Neutrino Observatories

**HAP Workshop Topic 4:
Advanced Technologies**

Program

- Neutrino detection from MeV to EeV energies
- Air shower physics with surface detectors
- Veto strategies
- Optical sensor development
- Radio and acoustic detection technology
- Design studies of future detectors
- New ideas

December 08-10, 2014
at RWTH Aachen

Local Organisation: Jörn Aufmuth, Christopher Weisbuch
Program Committee: Günter Anton (ZIN Erlangen), Klaus Heide (ZIN Kassel), Timo Ratz, Marek Kwiatkowski (DESY)

hap2014@physik.rwth-aachen.de
<http://hap2014.physik.rwth-aachen.de>

HELMHOLTZ ASSOCIATION
Alliance for Astroparticle Physics

RWTH AACHEN UNIVERSITY

www.hap-astroparticle.org

2014

Helmholtz Alliance for Astroparticle Physics

HAP Workshop 2015
AugerNext ASPERA Common Call Project

Program

- Innovative Research Studies for the Next Generation
- Ground-Based Ultra-High Energy Cosmic-Ray Experiment
- Improvement of EAS WLS radio detection
- Measurement of EAS data emission
- Improvement of photon detection
- Improvement of data communication
- Improvement of EAS muon measurements

January 20-22, 2015
at Karlsruhe Institute of Technology (KIT)

Local Organisation: Andrea Ferrari, Sabine Bader
Program Committee: An FR of the AugerNext Consortium

<https://indico.aicc.kit.edu/indico/event/AugerNext2015>

HELMHOLTZ ASSOCIATION
Alliance for Astroparticle Physics

KIT

www.hap-astroparticle.org

2015

Helmholtz Alliance for Astroparticle Physics

HAP Workshop 2016
Topic 4: Advanced Technologies

Highlight
Advancements of photosensor developments

- SIPMs
- Low temperature light detectors
- Large area photosensors
- Camera systems

Other topics

- ABRCAg astroparticle physics
- Digitizing analog signals at high sampling rate and bandwidth
- Optical readout at low temperatures
- Advanced technologies for air showers
- Real time detection
- Data Acquisition
- Intelligent triggers, digital data processing and event building
- Multi-channel readout systems (detector- and trigger-)
- Precision time synchronization in large scale experiments

February 01-02, 2016
at Johannes Gutenberg University, Mainz

Program Committee: Matthias Kiefgasse (KIT), Marco Weber (KIT), Sebastian Reuter (DESY, New Observers Group)

Local Organisation: Sebastian Böhm, Uwe Oberlack

<http://indico.aicc.kit.edu/indico/hap-topic4-workshop-2016>

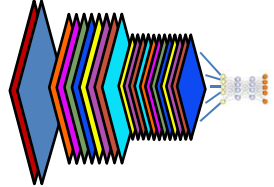
HELMHOLTZ ASSOCIATION
Alliance for Astroparticle Physics

KIT **PRISMA** **KFV**

www.hap-astroparticle.org

2016

HAP Workshop 2/2017



Big data in astroparticle physics

2017

This Workshop

<i>Robert LAHMANN</i> 17:00 - 17:15	Acoustics
<i>Thomas BRETZ</i> 17:15 - 17:30	SiPMs in Astroparticle Physics
<i>Christine PETERS</i> 17:30 - 17:45	SiPM FAMOUS & AMD
<i>Martin TLUCZYKONT</i> 17:45 - 18:00	HiScore
<i>Peter PEIFFER</i> 18:00 - 18:20	New Optical Sensors for IceCube-Gen2
<i>Tim HUEGE</i> 12:00 - 12:15	AERA
<i>Frank SCHRÖDER</i> 12:15 - 12:30	Radio detection of air showers with Tunka-Rex
<i>Radomir SMIDA</i> 14:00 - 14:15	Microwave signal of air showers measured with the CROME experiment
<i>Samridha KUNWAR</i> 14:15 - 14:30	Status and recent developments with TAXI
<i>Max RENSCHLER</i> 14:30 - 14:45	SiPM for Space Application
<i>Daniela DORNER</i> 14:45 - 15:05	FACT & M@TE - Monitoring at TeV Energies
<i>Andreas HAUNGS</i> 11:10 - 11:35	Technological Challenges next 5 years....

Acoustics (kHz)

(Silicon-) Photomultipliers

Air Cherenkov (non-)imaging

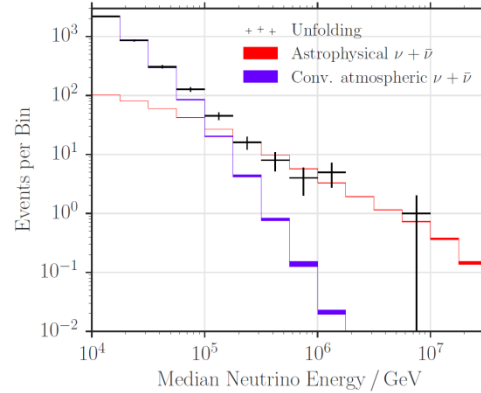
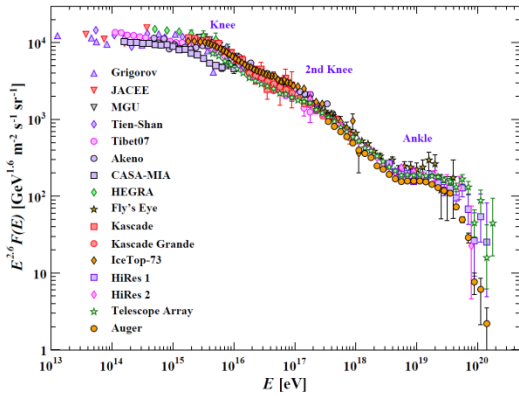
Radio (MHz, GHz)

R&D System (TAXI)

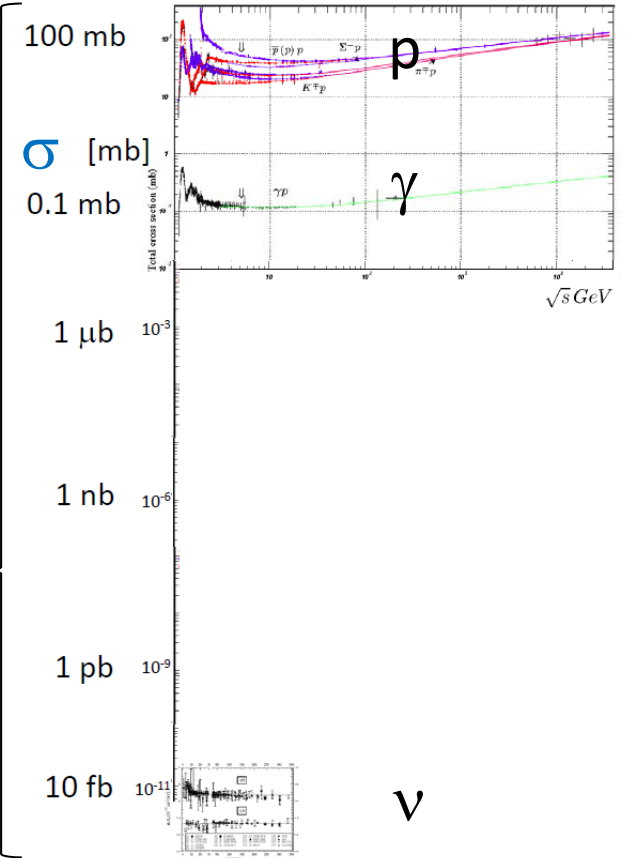
INSTRUMENTATION CALIBRATION MONITORING

Cosmic messenger detection challenge

flux of cosmic messengers



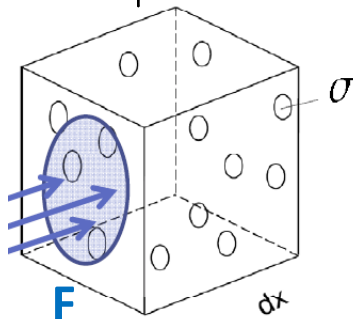
cross section



measured event rate

$$\dot{N} = \frac{\dot{N}_{\text{cosmic}}}{F} \cdot n_{\text{target density}} \cdot (F dx)_{\text{target}} \cdot \sigma$$

Natural giant target volumes

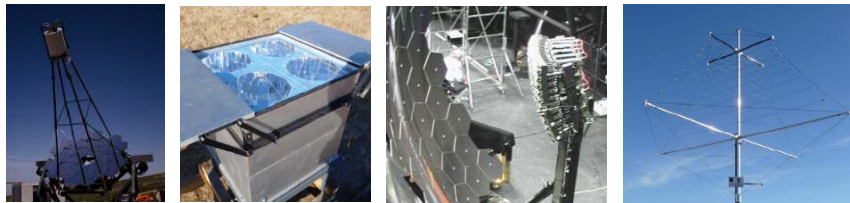
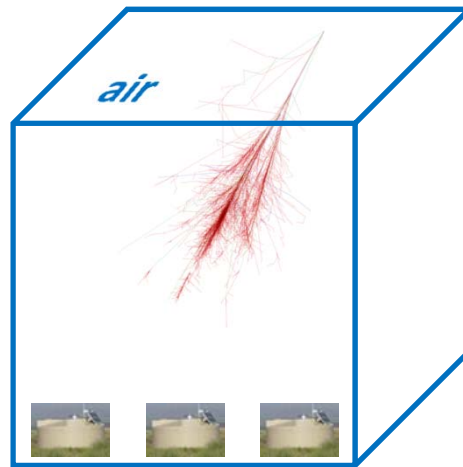


Natural giant target instrumentation

nuclei, photons

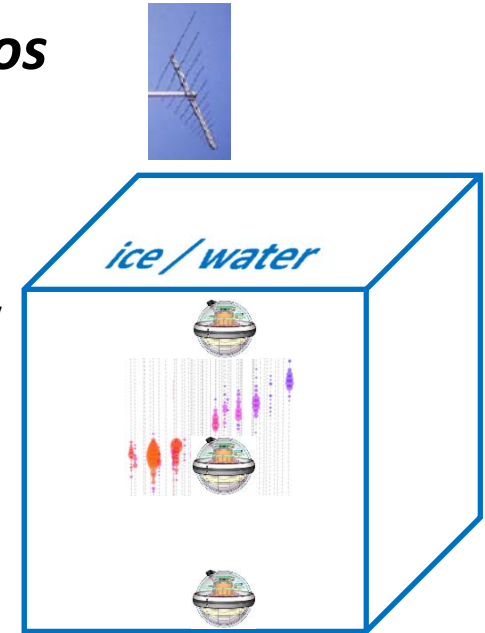
Cherenkov
Fluorescence
Radio

Particle



neutrinos

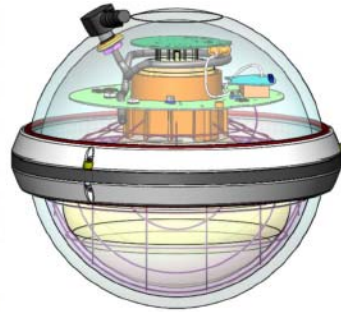
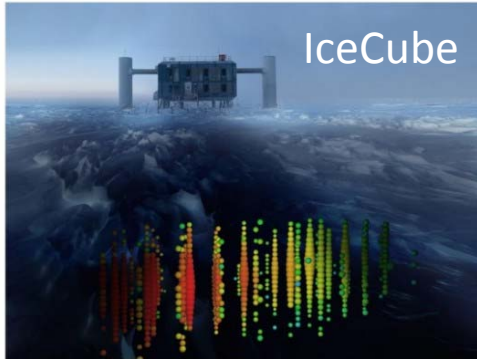
Cherenkov
Acoustics
Radio



Instrumentation ! Monitoring ! Calibration !

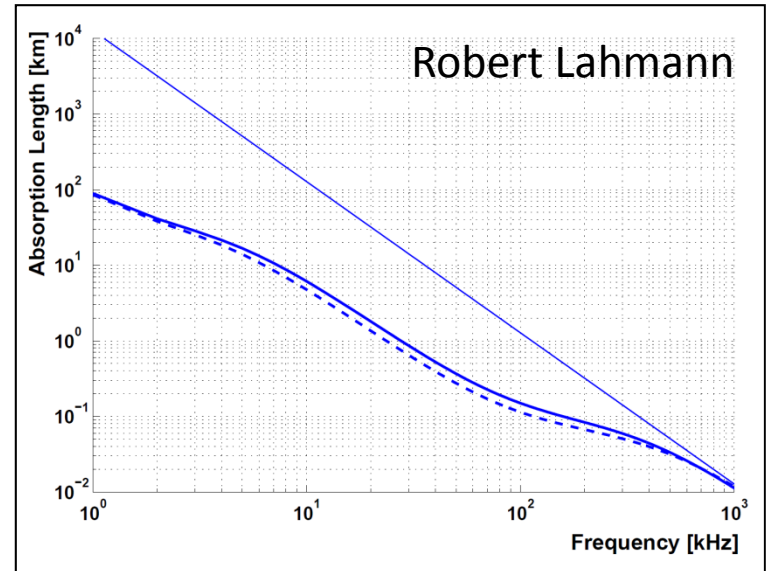
Instrumentation

Cherenkov light in ice

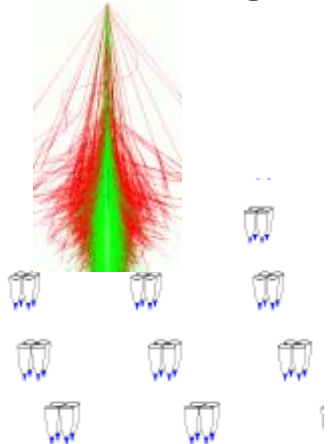


Peter Peiffer

Thermo-acoustic effect



Cherenkov light in air

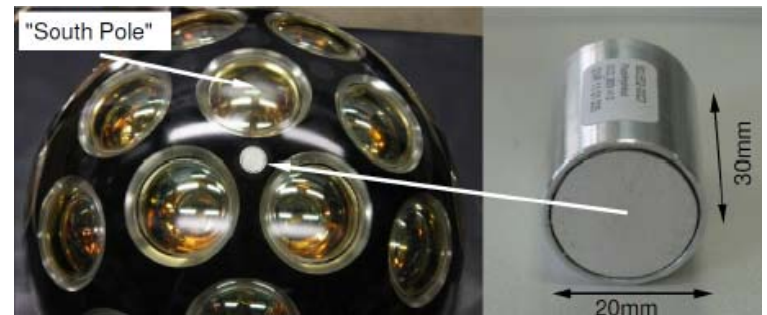


Martin Tluczykont
HiScore



KM3NeT

piezo sensor



Instrumentation & Monitoring

Fact

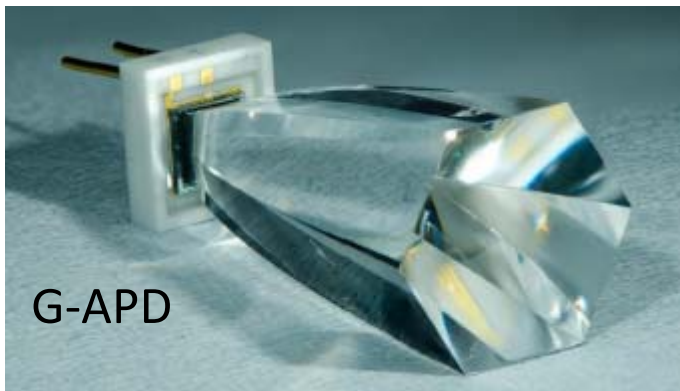


TAXI

Samridha Kunwar



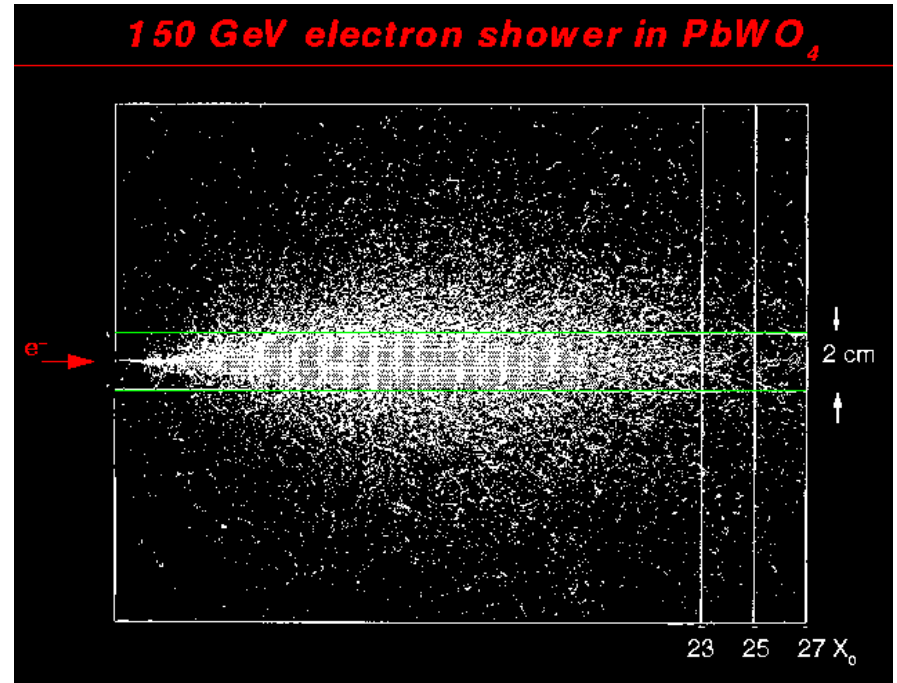
G-APD



Photomultipliers and Silicon Photomultipliers:
a race for most efficient photon detection

Thomas Bretz, Daniela Dorner,
Christine Peters, Max Renschler

Calibration: usually by test beam



...but for EeV energies?

Energy Calibration: by radiation energy

First principles: Electrodynamics

30-80 MHz



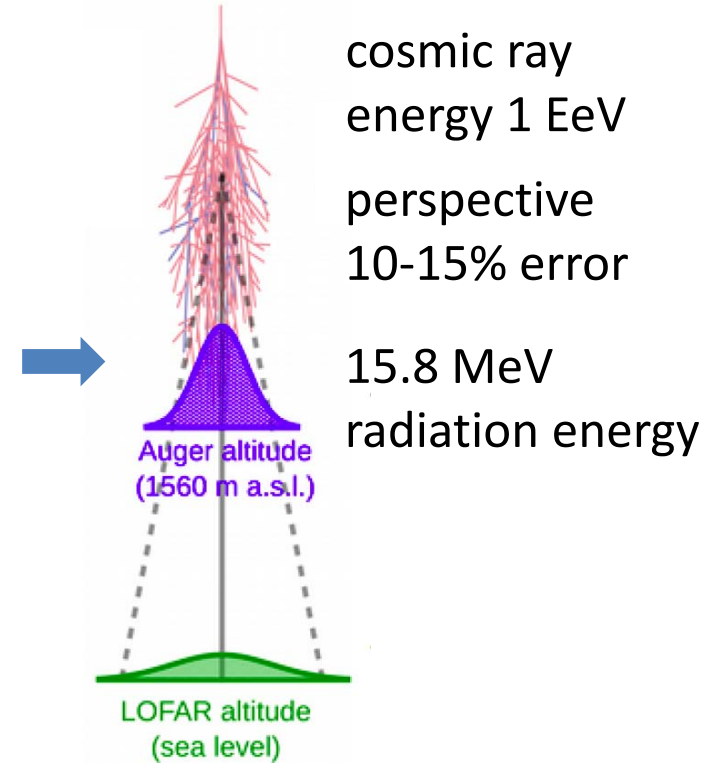
Cosmic-ray
energy estimator

Radiation energy
of air shower [eV]

Energy
fluence [eV/m²]

Electric field [V/m]

Voltage [V]

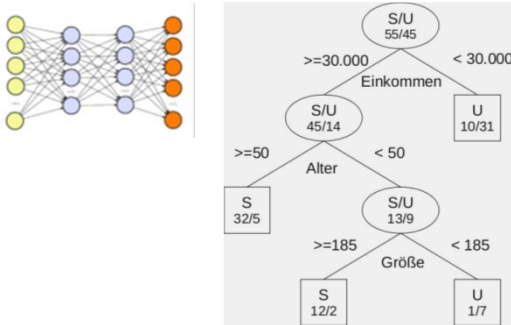


Radio: Tim Huege, Radomir Smida, Frank Schröder

DEEP LEARNING

Deep Learning

Since 1990s: Neural Networks,
Boosted Decision Tree, etc.



- Signal / Noise
- Particle identification

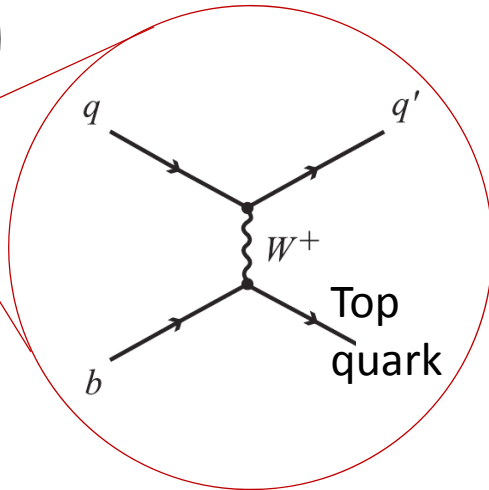
Since 2006: Deep Learning



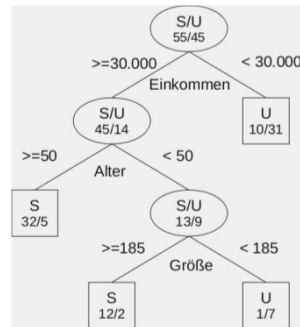
- Speech recognition
- Image recognition
- Pattern recognition
- Anomaly detection
- Ambiguity solving
- Multi-Classification
- Autoclassification (unsupervised learning)
- ...

Multivariate Analysis Methods (MVA)

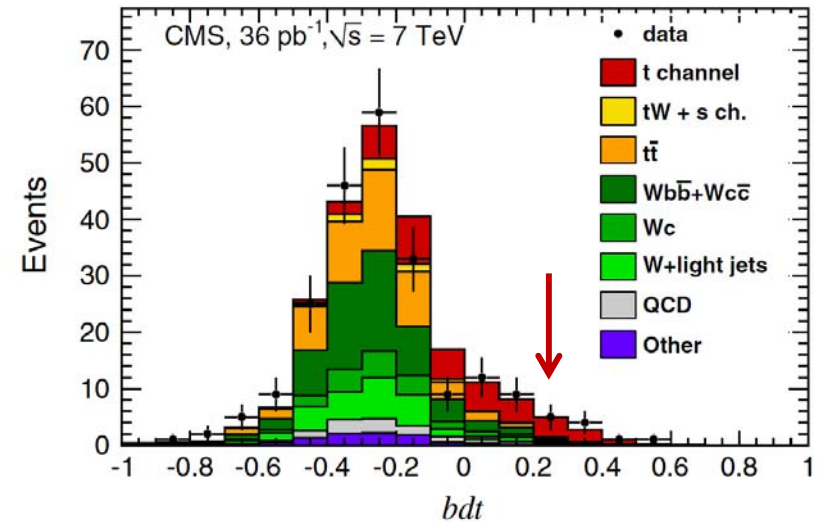
2010
CMS Data
36 pb⁻¹



Boosted
Decision
Trees

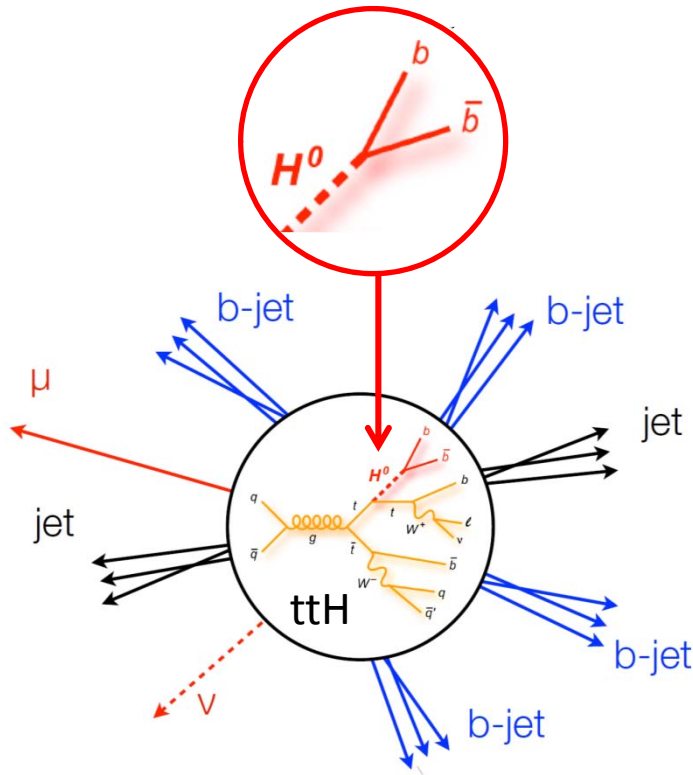


Dennis Klingebiel Aachen PhD student
PRL **107**, 091802 (2011)



First measurement at LHC !
with only 1/30 of the luminosity
compared to initial estimates

Ambiguity solving: Higgs \rightarrow bb

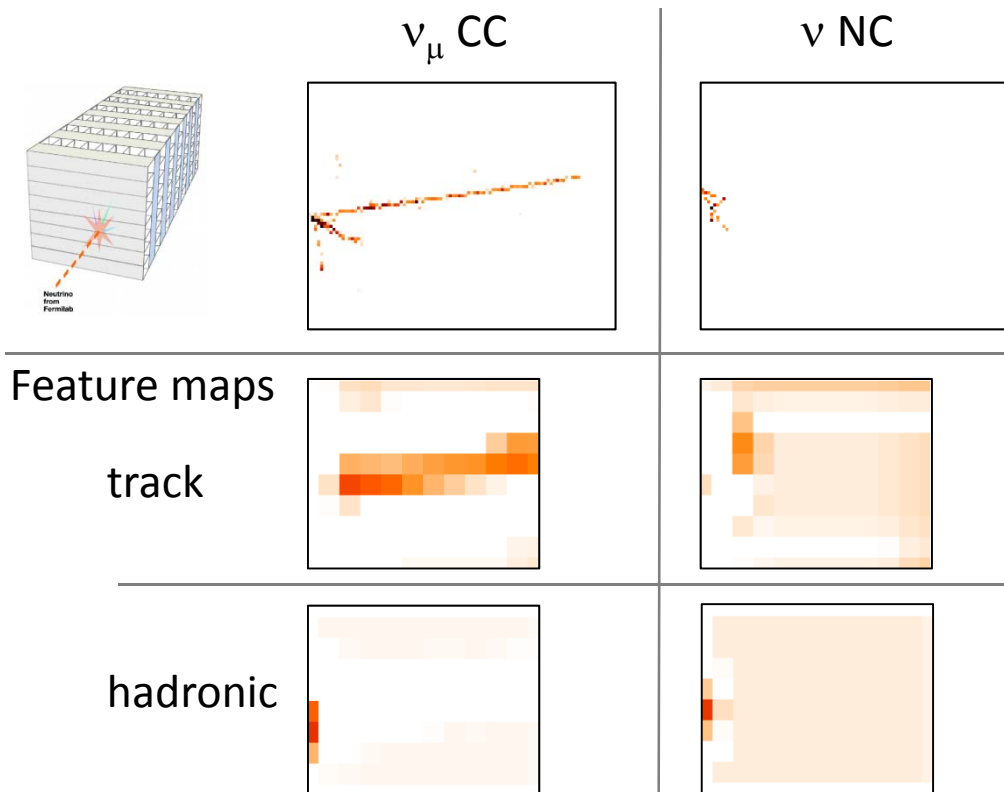


Benjamin Fischer Aachen Bachelor student, 2015

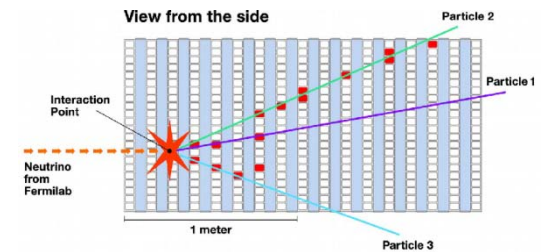
Method	Higgs finding efficiency
Boosted decision tree	35%
Deep learning neural network	52%

Deep learning solved ambiguities better by 50% !
exploiting „high level“ observables (physicists ideas)
plus „low level“ observables (e.g. particle px, py, pz)

A convolutional neural network neutrino event classifier



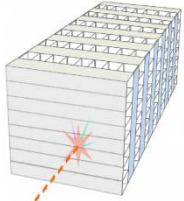
NOvA neutrino oscillations



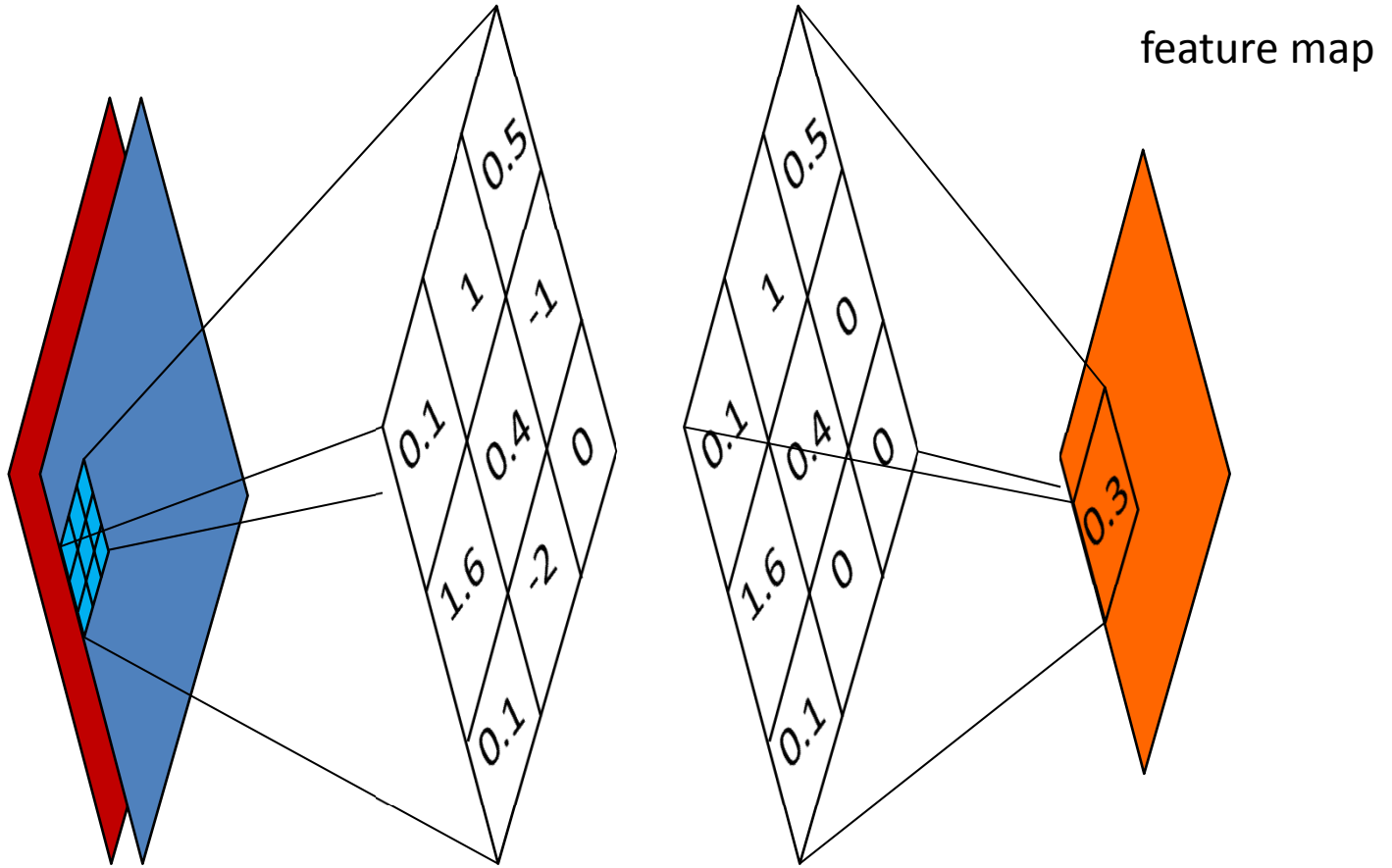
Method	ν_e efficiency (same purity)
Physicists algorithm	35%
Deep learning neural network	49%

Convolutional Neural Networks

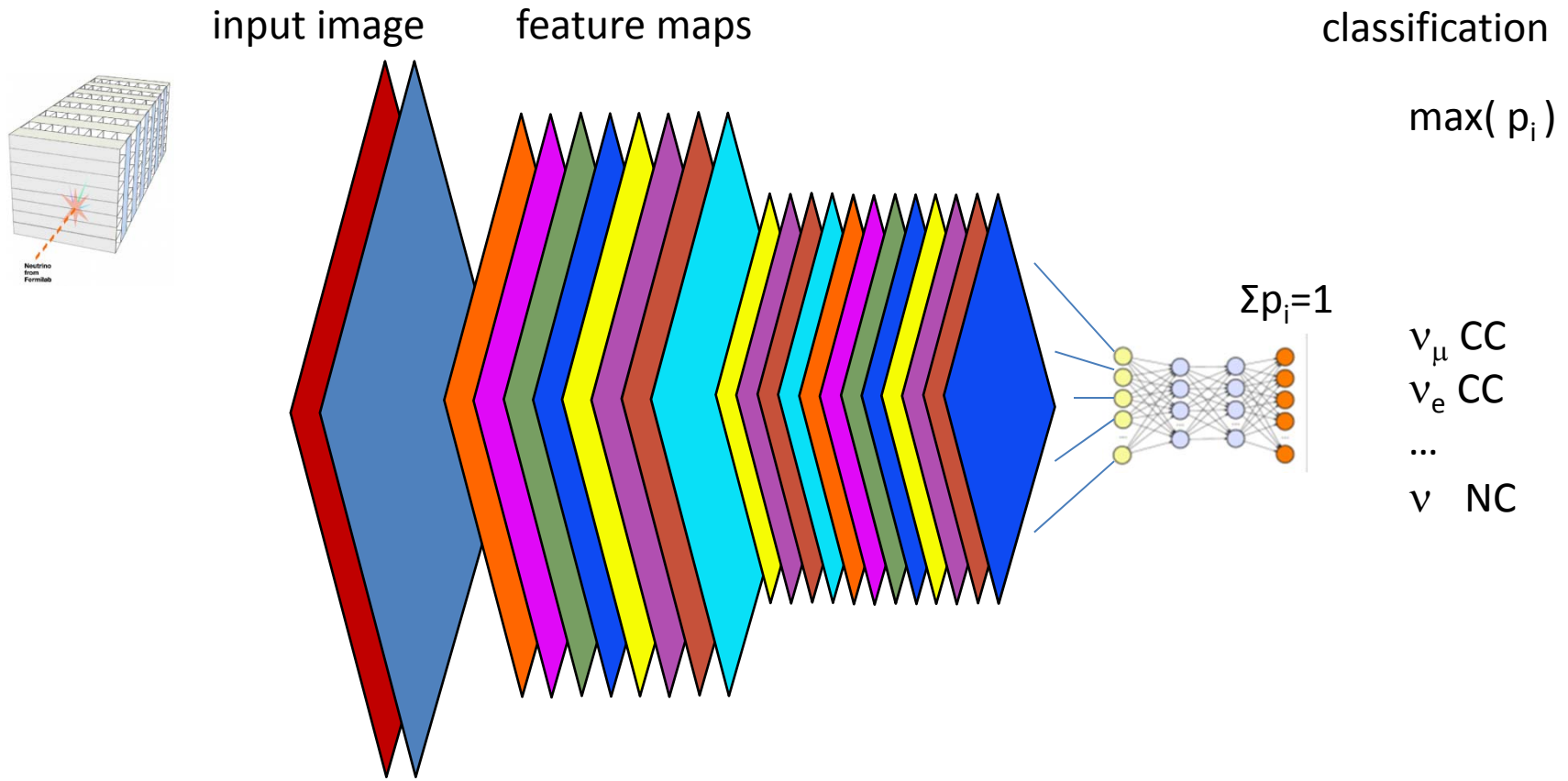
input image
(2 projections)



$$y = ax + b \quad \rightarrow \quad z = \max(0, y) \quad \rightarrow \quad \langle z \rangle$$



Convolutional Neural Networks



Deep Learning in Astroparticle Physics

Physicist supported by deep learning techniques to maximally exploit experimental data

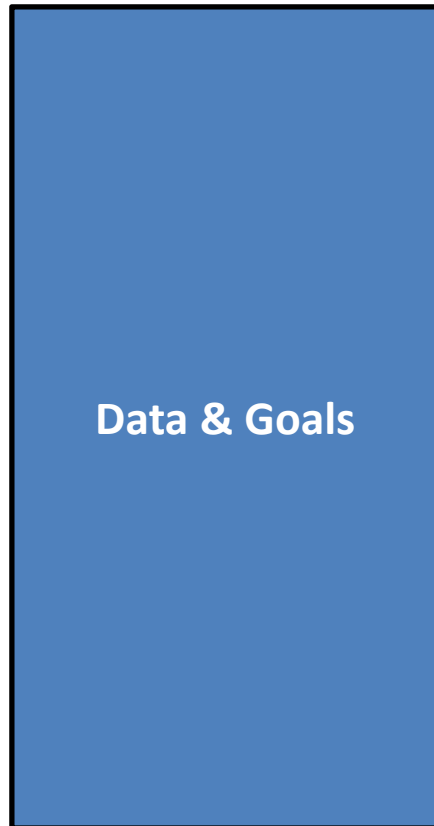
Common instruments & knowledge

- Projects benefiting from deep learning
- Data assessment for deep learning
- Deep Learning network design
- Performance & diagnostic tools
- Optimization strategies

Data characteristics

Astroparticle physics

„Standard“



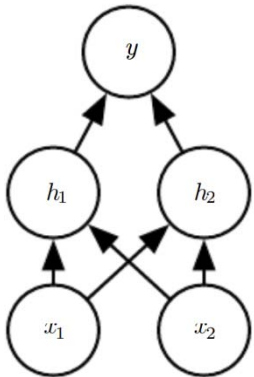
Dimension	Single channel	Multi-channel
1 D	Audio waveform	Skeleton animation data
2 D	Audio data (Fourier transformed)	Color image data
3 D	Volumetric data (e.g. medical imaging)	Color video data

„Deep Learning“ I. Goodfellow, Y. Bengio, A. Courville, MIT Press in press
<http://www.deeplearningbook.org/>

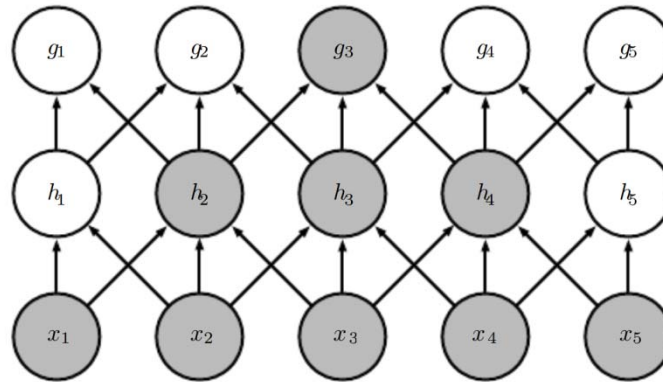
➔ New data classifications ?

Neural Network Architectures

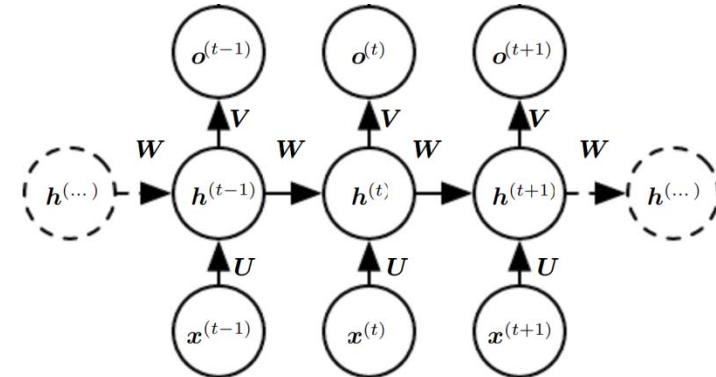
Feed forward



Convolutional

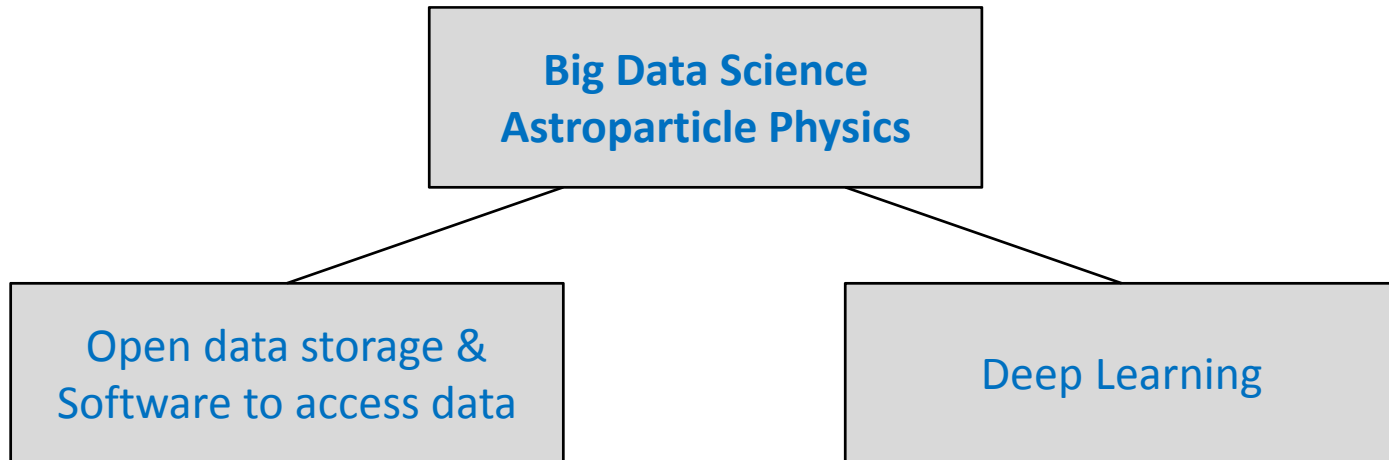


Recurrent



many variants & combinations can be inherited from deep learning research

HAP Workshop 2/2017



HAP workshop on

Big Data Science in Astroparticle Physics

Feb 2017

@

RWTHAACHEN
UNIVERSITY

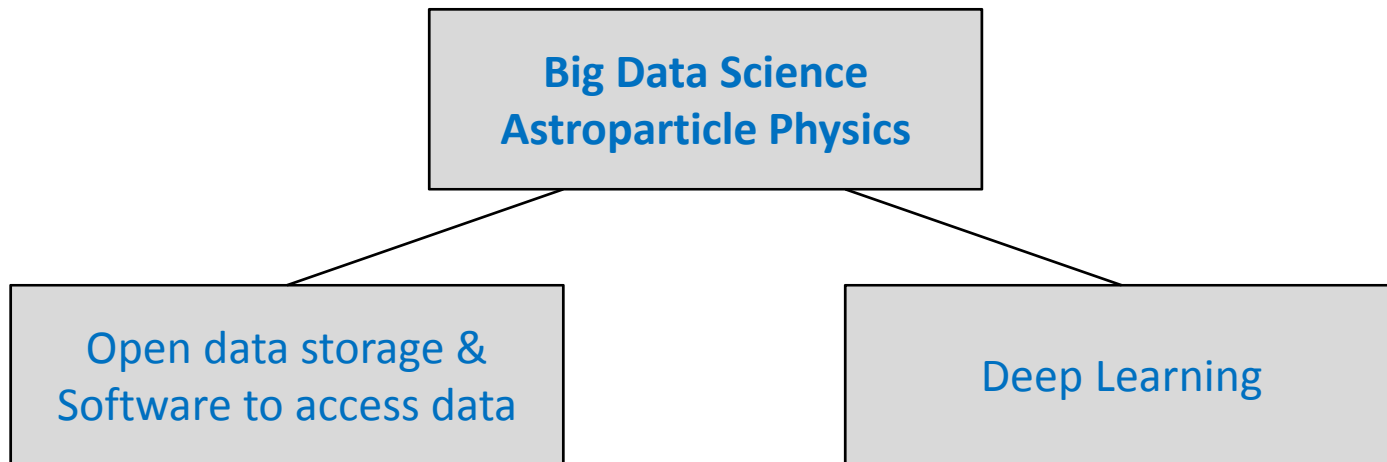
Martin Erdmann, Andreas Haungs

Big Data Science: Astroparticle Physics

Digitale Agenda

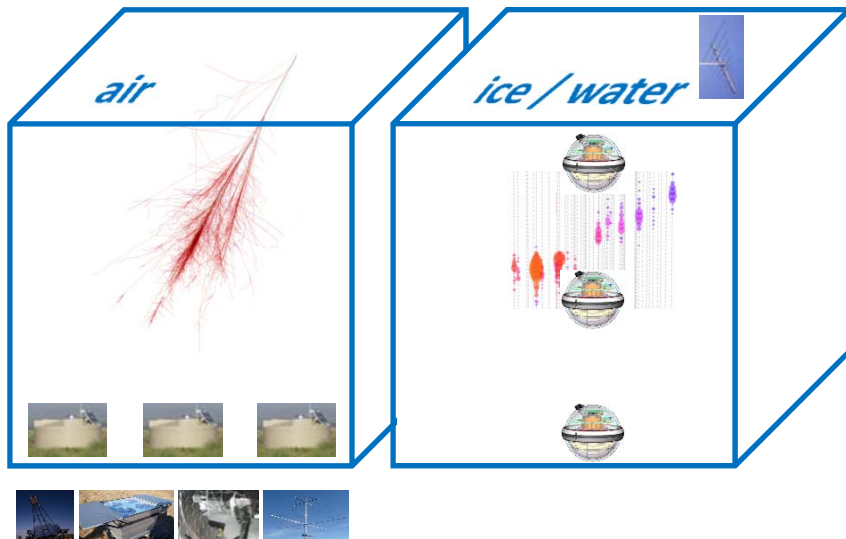


1. Digitalen Wandel in der Wissenschaft forcieren
2. Zugang zu Wissen als Grundlage für Innovation sichern
3. Bildungsoffensive für die digitale Wissensgesellschaft
4. Innovationspotenziale der Digitalisierung nutzen
5. Durch Forschung den digitalen Wandel verstehen
6. Kultur und Medien



Summary

**Exciting progress:
instrumentation + calibration +
monitoring of natural giant
target volumes**



**Action item:
deep learning becoming
central to exploiting
astroparticle measurements**

