# The Amiga Muon Detector - System Tests and Preparation of the Prototype Detector in Malargüe

Peter Buchholz, Ivor Fleck, Uwe Fröhlich, Yury Kolotaev,
Olga Perkova, Michael Pontz, Rodica Tcaciuc, Martin Tigges

*University of Siegen – Department of Physics*

In collaboration with

Alberto Etchegoyen, Manuel Platino, Oscar Wainberg
*Centro Atomico Constituyentes Buenos Aires*

Mariela Videla, Gonzalo A. de la Vega
*Universidad Tecnologica Nacional Mendoza*

Zbigniew Szadkowski
*University of Lodz*

Schule für Astroteilchenphysik
Obertrubach-Bärnfels, 07. - 15. Oktober 2009

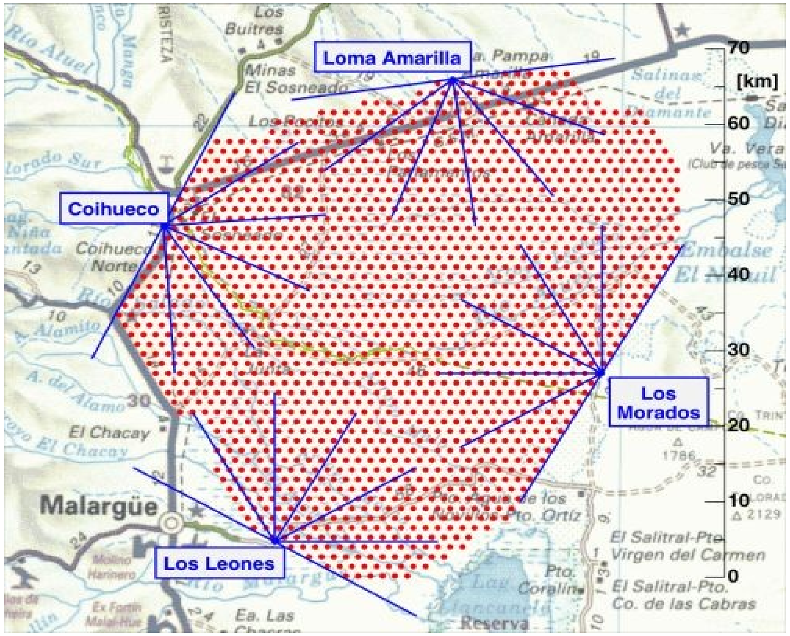
SPONSORED BY THE
Federal Ministry of Education and Research

DAAD Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

PIERRE AUGER OBSERVATORY

UNIVERSITÄT SIEGEN

# The Pierre Auger Experiment




- The Pierre Auger Experiment is located in Argentina, namely near Malargüe, province Mendoza.
- Physics: Survey on high energetic cosmic rays at energies above $3 \times 10^{18}$ eV.
  - 1600 water Cerenkov tanks in a 1500 m grid covering 3000 km².
  - Four locations with 24 fluorescence telescopes overlooking the tank array.

*www.auger.org, 2009*

# Enhancements of the
# Pierre Auger Experiment

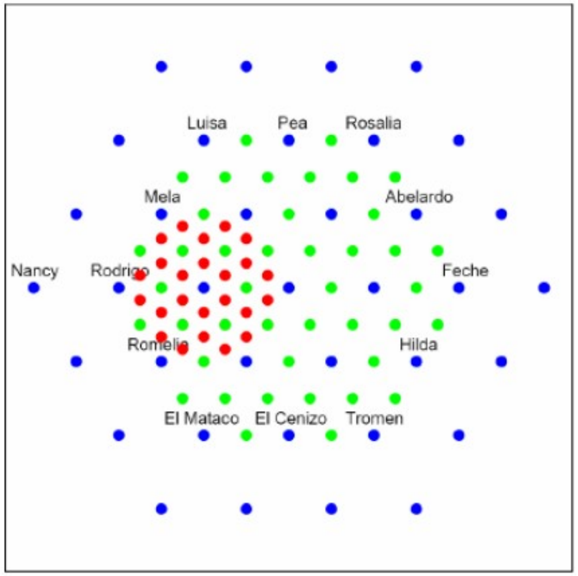
- AREA (Auger Radio Engineering Array):
  Direct detection of the electromagnetic component of an air-shower.

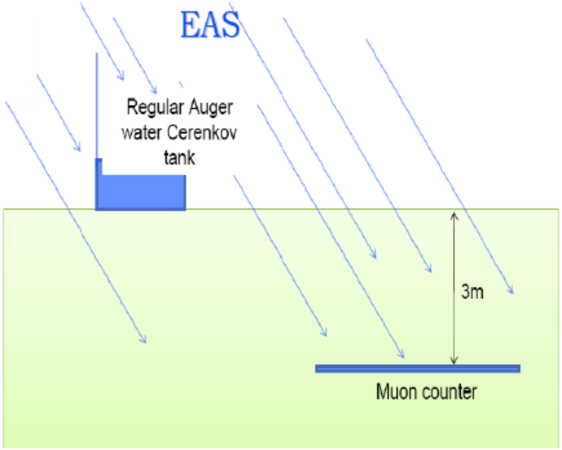
- HEAT (High Elevation Auger Telescopes):
  Three additional telescopes for the Infill looking at angles where low energetic showers fluoresce.

- AMIGA (Auger Muons and Infill for the Ground Array):

  - Decrease of the grid spacing in a sub-part of the array (the Infill near Coihueco: ca. 25 km²).
    -> Lowering of the full trigger efficiency to an energy range between $10^{17}$ and $10^{18}$ eV.

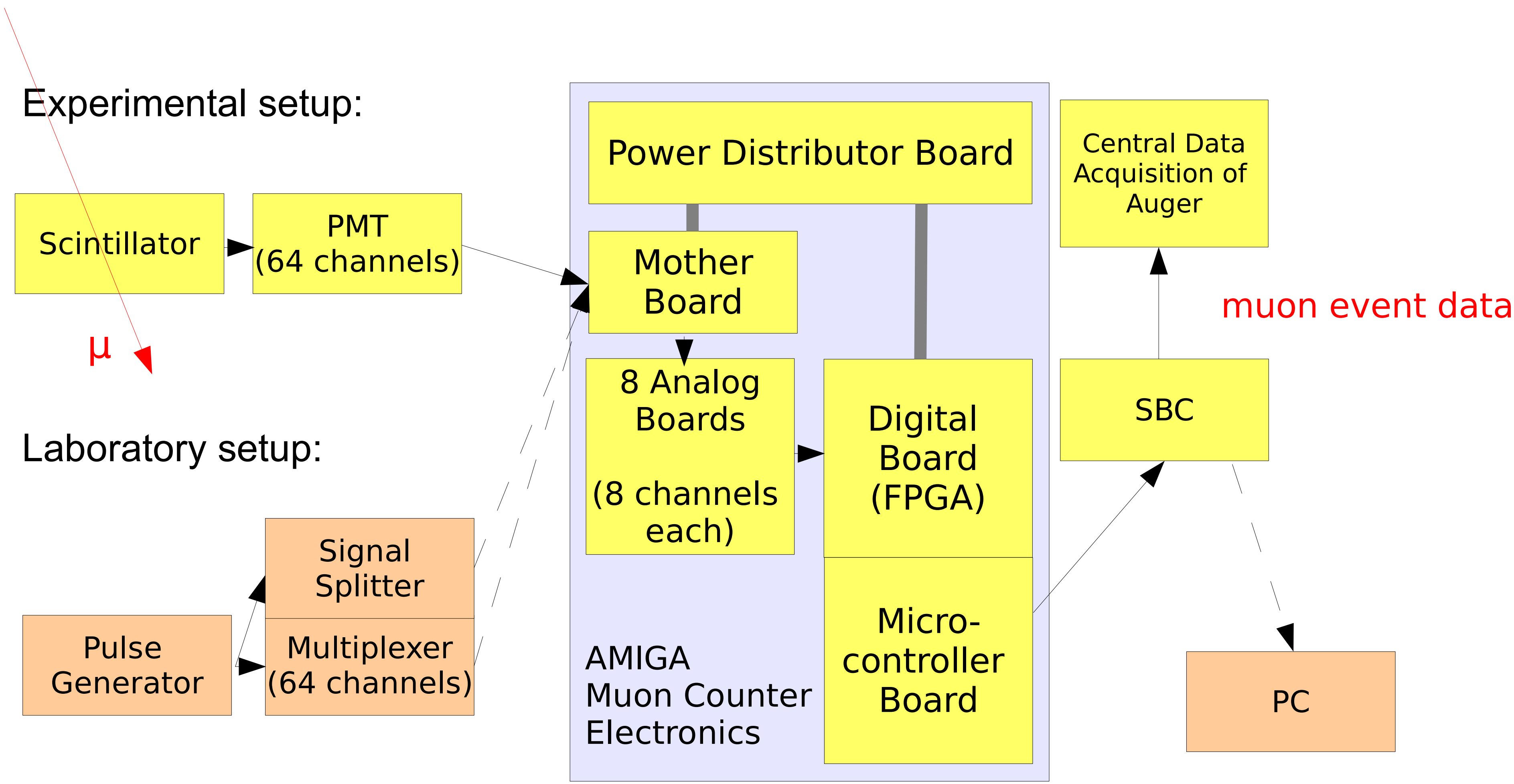
  - Installation of underground muon detectors (30 m² each) at each of the 85 Infill tanks.
    -> Direct measurement of the muon-number in an air-shower for e.g. composition analysis.



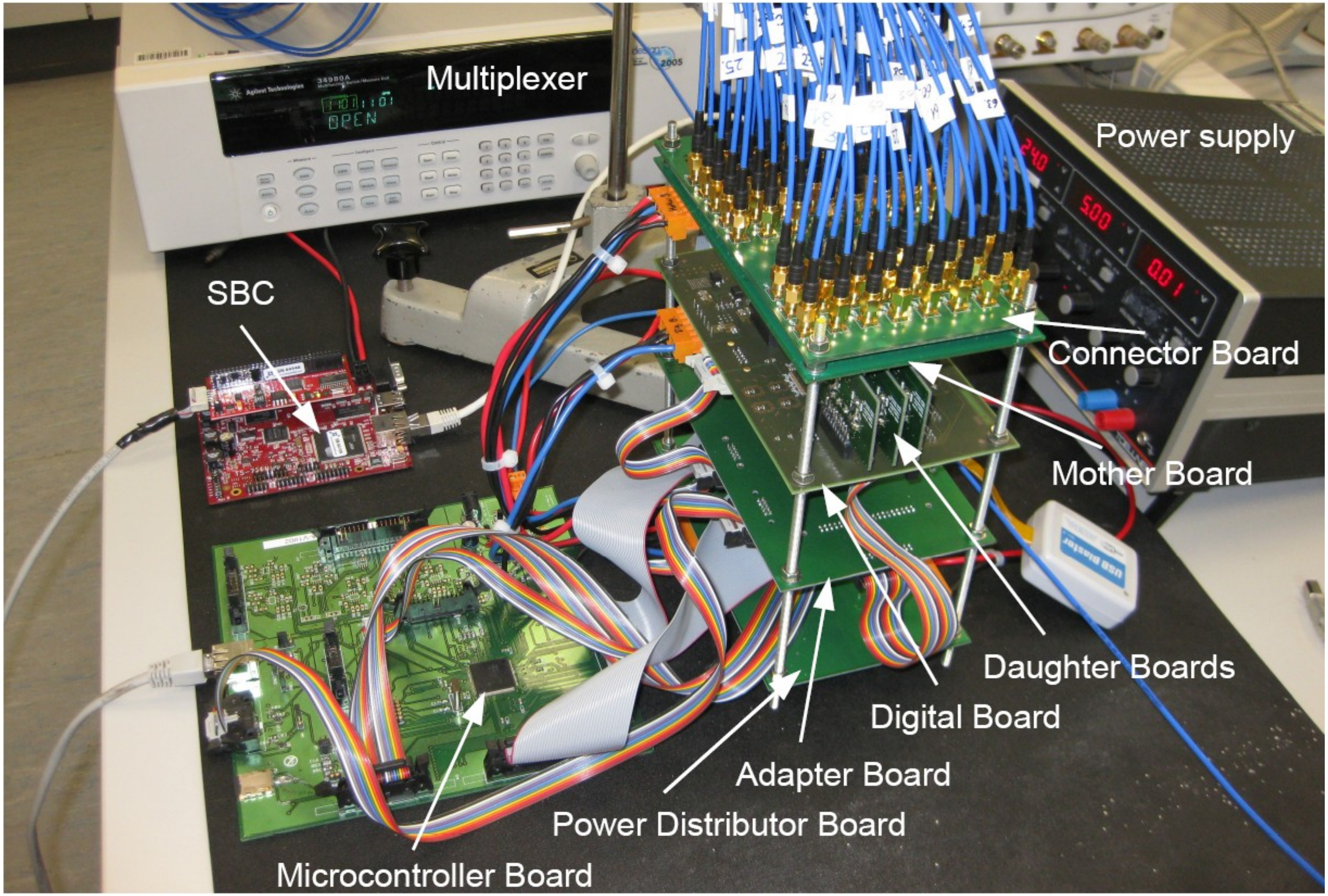

*E. Santos, 2007*

# Data flow in AMIGA



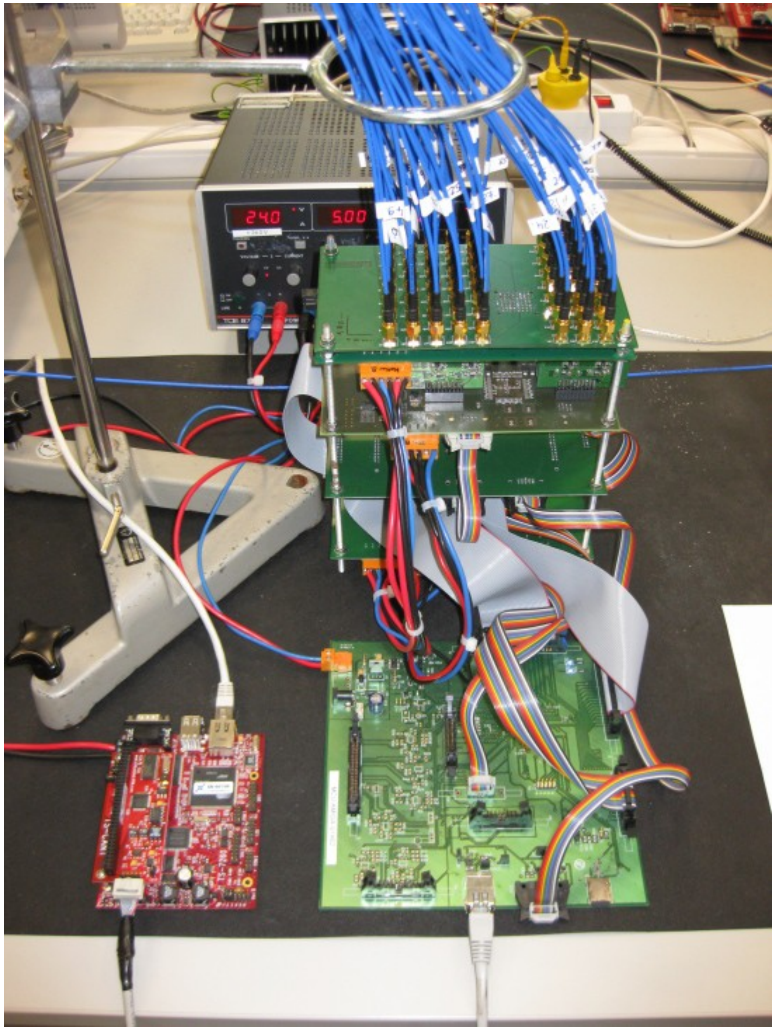

► experimental task: Provide muon number of showers triggered by the SD array.

# Laboratory Setup



# AMIGA System Tests

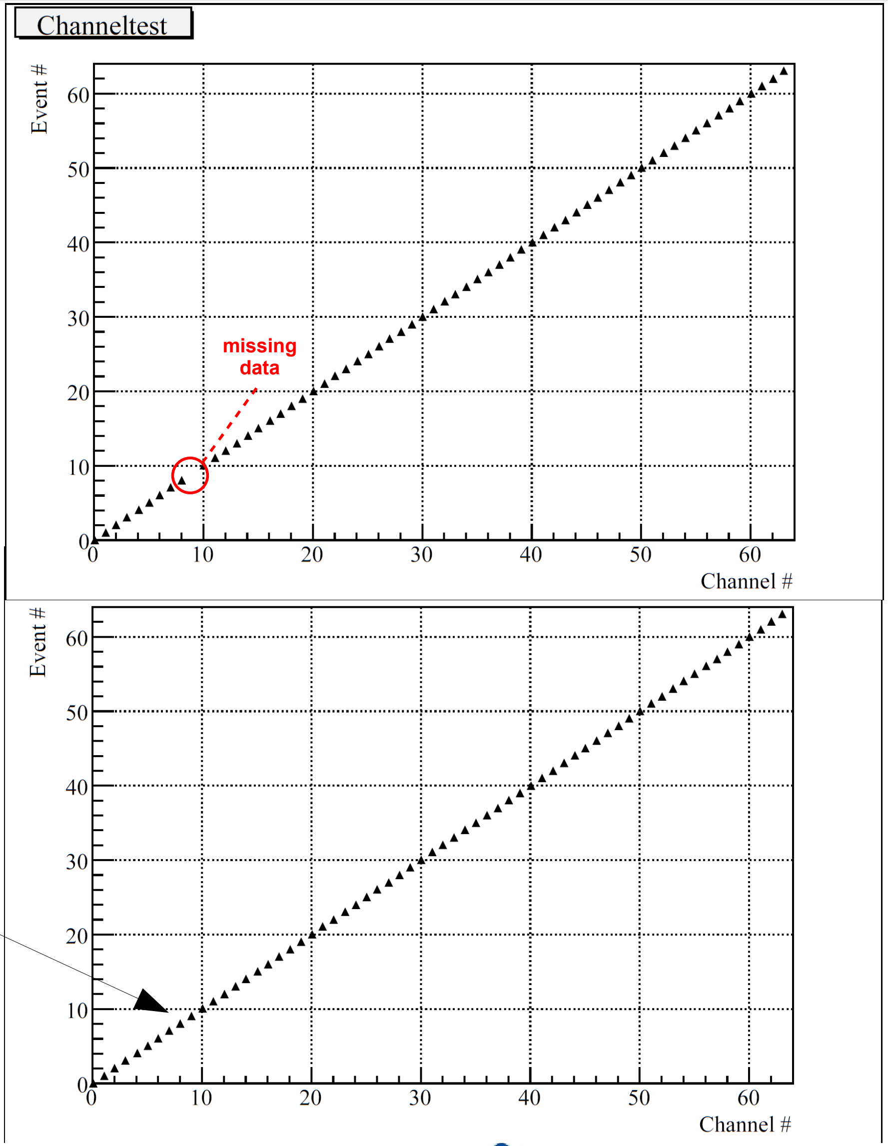
- Large amount of electronics boards (each of the 85 Infill tanks will be equipped with 4 muon counter setups -> ca. 2800 single boards) require automated tests of the fully assembled AMIGA electronics system.
  - channel identification and functionality
    channel test
  - crosstalk
  - noise
  - threshold scans
    (characterization of all channels,
    esp. comparators on Daughter Boards)
  - temperature cycles



*AMIGA prototype setup in the laboratory in Siegen.*

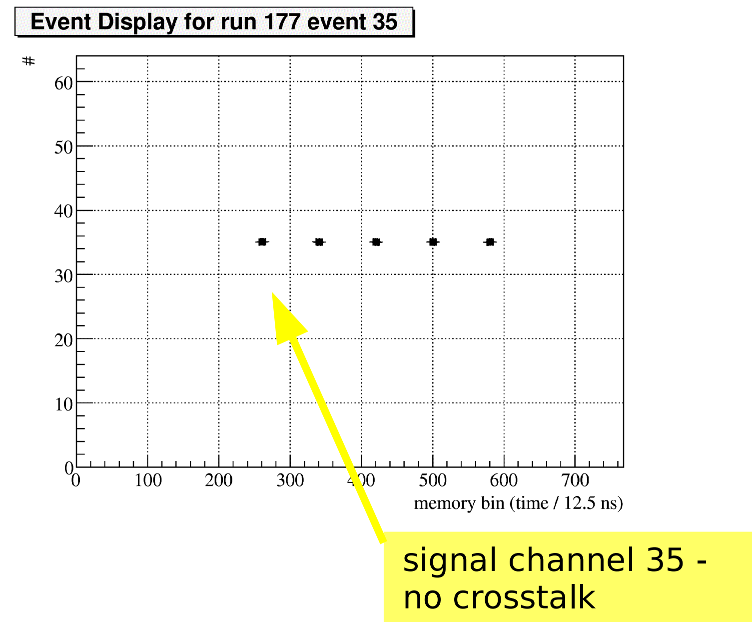
# Basic functionality: Channel test

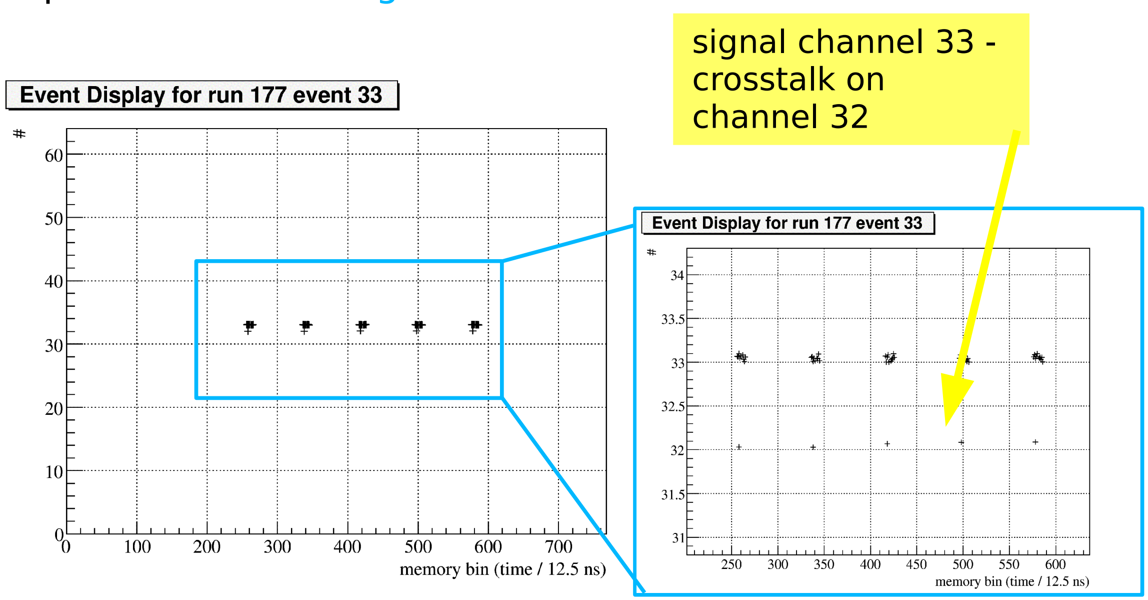
- Analog signal sent to only one channel.
- Analog signals need to be above a given threshold (seperately programmable for each channel).
- Data should represent only that channel.
- Missing data hints at defects in the electronics (e.g. cold soldering joints, broken chips, bad contacts on connectors).
- Everything ok after investigation and rescan.



# Crosstalk Runs

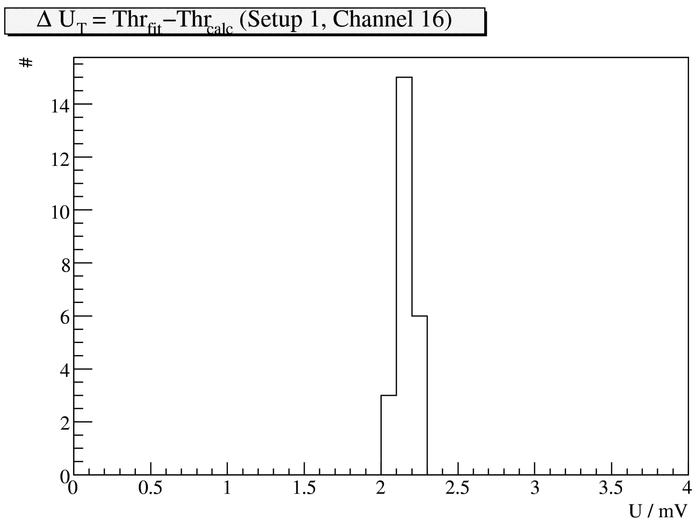
- Threshold voltage set to 3.5 mV (+ offset).
- Trigger on any signal on any channel.
- sequence of 5 pulses (period 1 µs, width 28 ns, amplitude 800 mV) sent to only one channel
- 800 mV >> signal amplitude of PMT pulses (< 15 mV)
- Crosstalk only seems to appear for very high signal amplitudes -> real signals are not affected.



# Outlook

- Full characterization of all AMIGA prototype systems in the laboratory.
- Installation of a first prototype in November with 2x 2 m scintillator elements.
    - Operational tests with that prototype.
    - Tests of the trigger system.
    - Test of the telecommunication with and within the AMIGA muon counters.
    - Data analysis.
- Post-prototype period: mass production for the equipment of 85 tanks (Infill array) with 3 AMIGA muon counters each.




*Voltage offset on channel 16 (Setup 1).*

# Summary

- AMIGA as one enhancement of the Pierre Auger Experiment.
- Data flow of the AMIGA muon counters.
- System tests in Siegen on the prototype setups
    - Basic functionality test, crosstalk data analysis as examples.
- Next steps:
    - Further studies on the full AMIGA electronics, data analysis, preparation for the Malargüe prototypes and for the mass production in the post-prototype period.
    - Prototype installation in November 2009 in Malargüe, Argentina.

*The future: Installation of AMIGA muon counter detectors.*

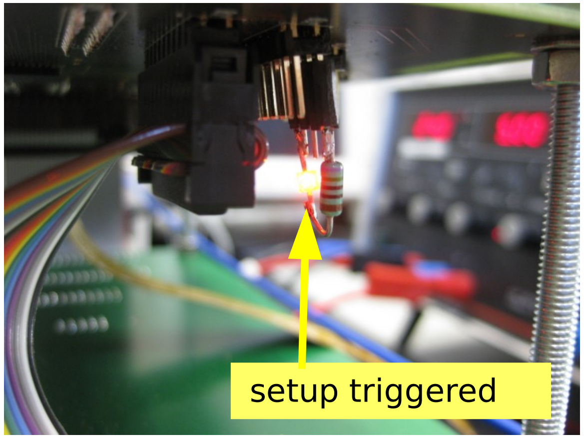




UNIVERSITÄT SIEGEN

# The AMIGA Trigger Modes

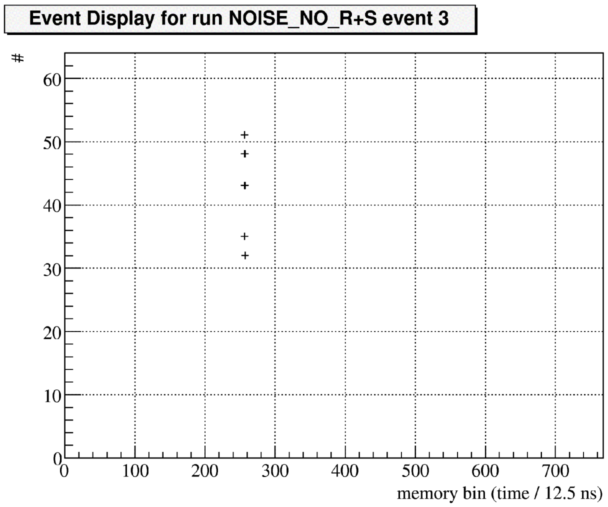
- internal triggers
  - occupancy trigger:
    N channels need to have a signal
    in the same 3 ns time bin
  - coincidence trigger with additional
    external scintillators
  - ➔ system tests in the lab
    as well as first data taking at the site

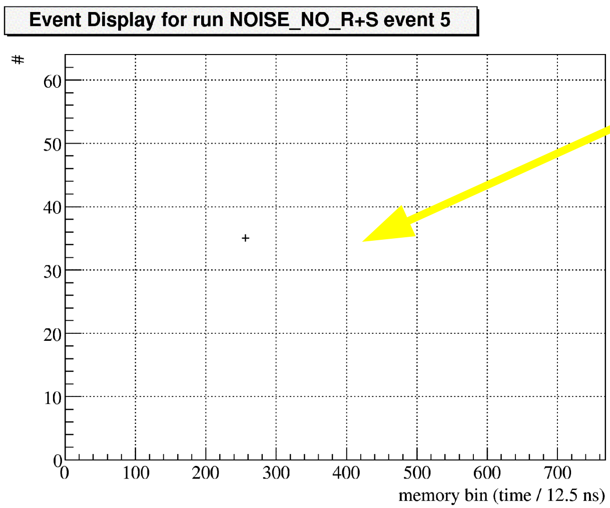



- external trigger (final trigger design)
  - Auger T1 trigger signal from SD tank
    - every triggered muon event are locally stored
  - Auger T3 trigger request from CDAS
    - muon event data are transferred to CDAS
  - ➔ no data traffic for triggers less than T3 (rate < 1 Hz)

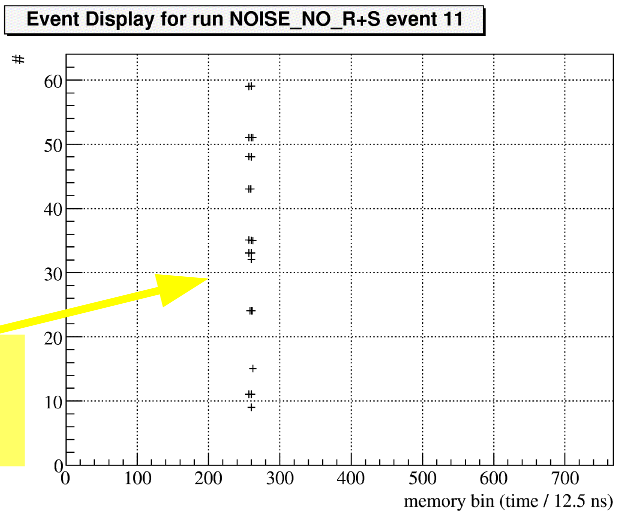
# Noise Runs

- threshold of comparators set to 0.5 mV (+ offset)
- trigger on any signal (occupancy trigger set to 1)
- about 22 hours of recording time:
  13 events triggered
- noise runs under study




thermal noise




some power supply switched on in the lab

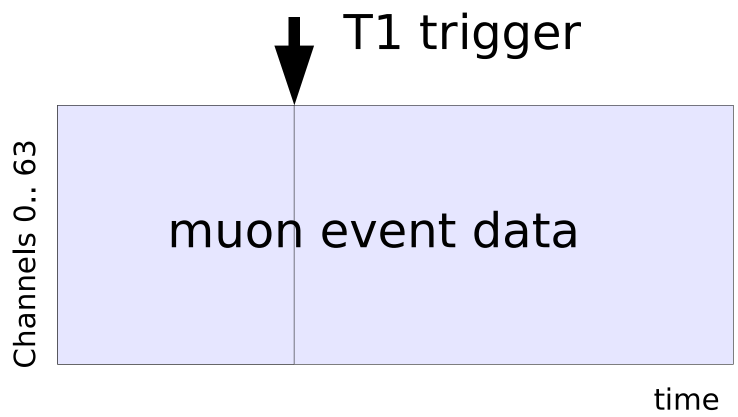




UNIVERSITÄT SIEGEN

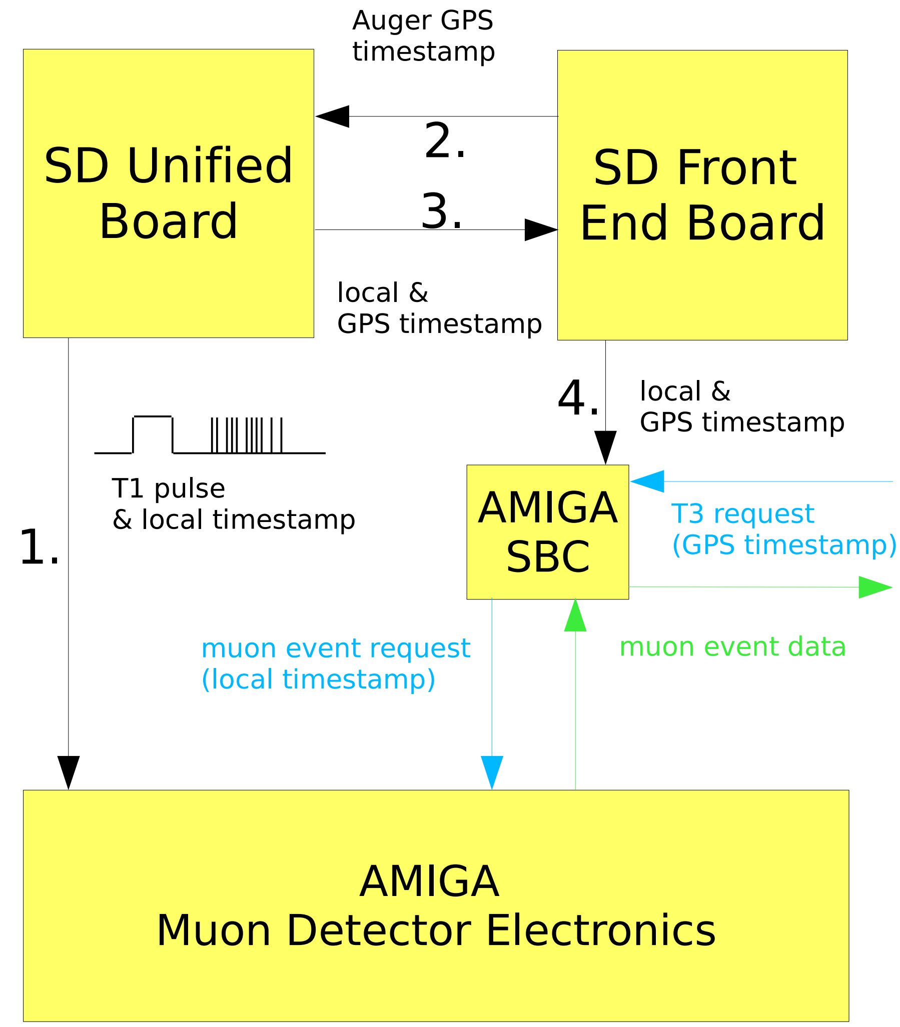
# External Trigger

- AMIGA muon event structure:




- AMIGA needs T1 trigger signal but the GPS timestamp is generated much later
    - ➔ AMIGA will work with local timestamps underground
- on Auger T3 request:
translation between GPS timestamp to local timestamp in the SBC

➔ muon events with Auger GPS timestamps



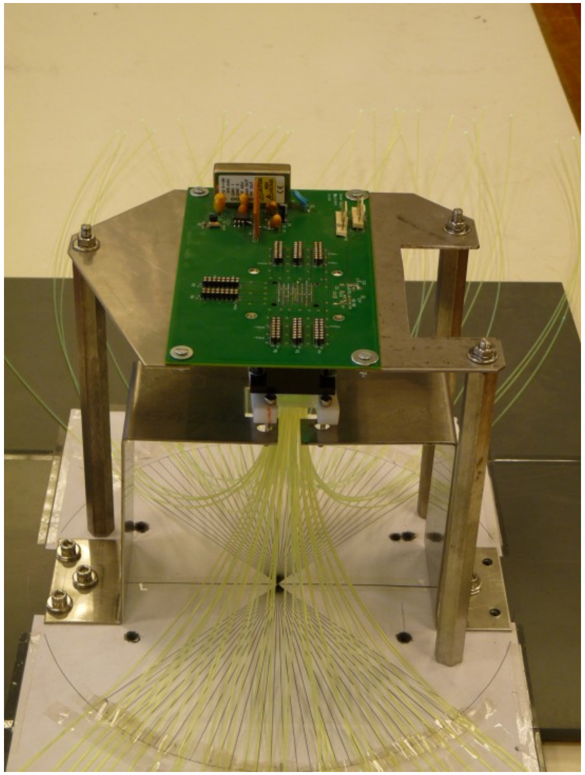





UNIVERSITÄT SIEGEN

# Outlook for Malargüe

- installation of a prototype with 2x 2m scintillators in November, 64 channels, prototype electronics, operational tests for about 2 months
  - basic functionality verification
  - data taking with occupancy trigger and storage of events on local hard disk (no stress of the telecommunication)
  - data taking with external trigger system
  - ➔ test of full telecommunication up to CDAS
- data analysis: correlations of internally triggered events with Auger T3 trigger
- tests in the field are tests for the active and passive materials and the detector design
- installation of a 2x 4 m-scintillator prototype (same electronics) and operational tests (shorter test period)
- coincidences between the two prototypes
- equipment of the Unitary Cell (7 tanks) in spring/summer 2010

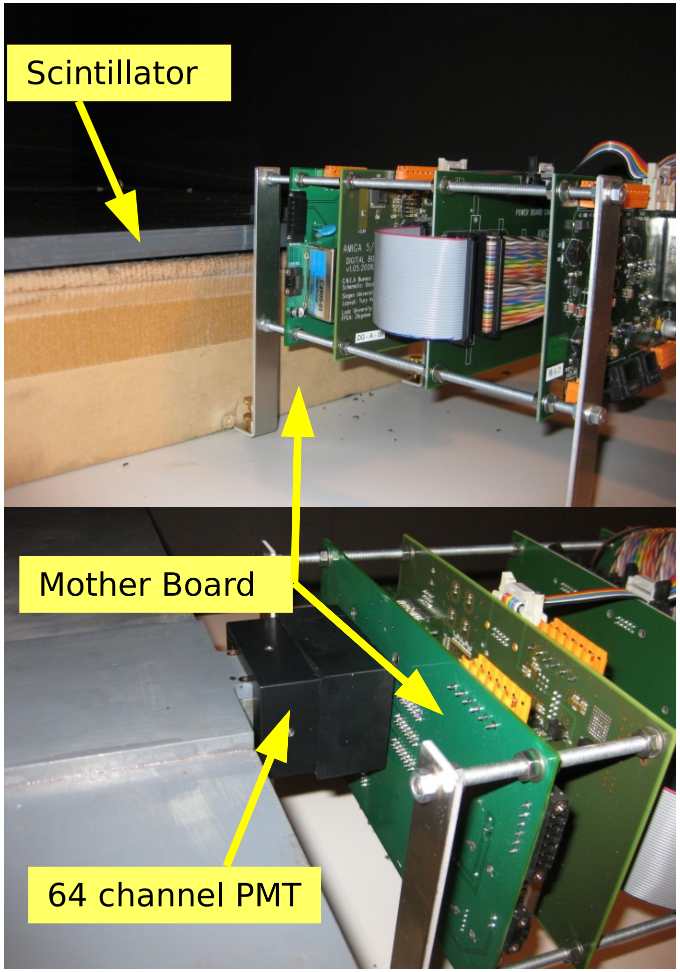


*Connection of the optical fibres to the electronics in the laboratories in Buenos Aires.*

# Scintillator Test Setup

- another complete prototype setup in a dark lab
- connected to a 64 channel PMT and 16 scintillator strips (each 1 m)
  - each fibre will cover up to 9 PMT channels
  - scan of the the 16 strips with a Cs137 source to learn about alignment of the fibres
  - recording of real air showers
    - ➔ usage of additional coincidence counters
    - ➔ occupancy trigger only and correlations with coincidence counter signals

➔ experiences for Malargüe for the prototype and the final detector design




*Scintillator test setup in the dark lab in Siegen.*