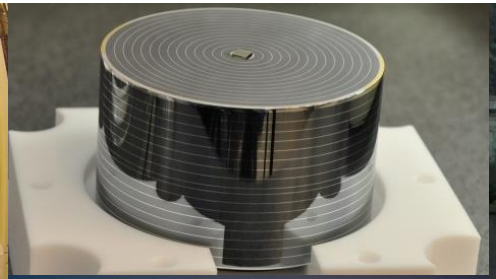
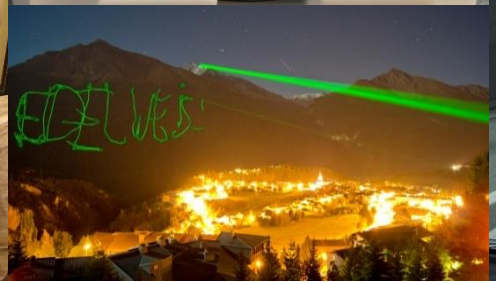
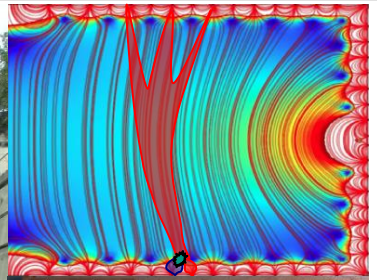
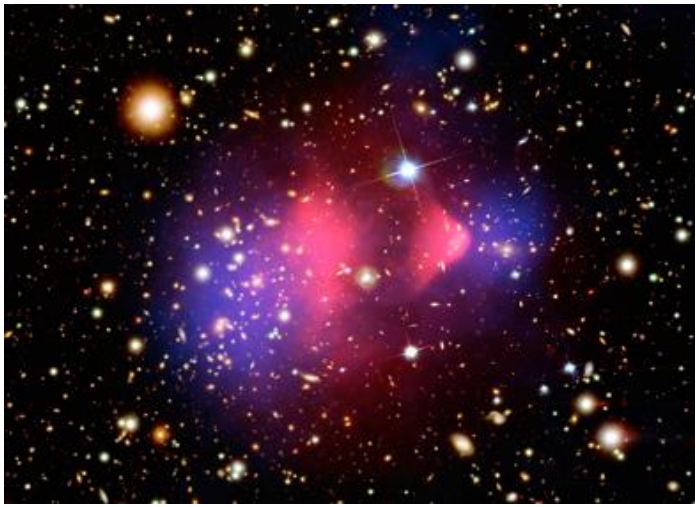
DAQ systems for Dark Matter Search
EDELWEISS-III and EURECA

Bernhard Siebenborn, Institut für Kernphysik

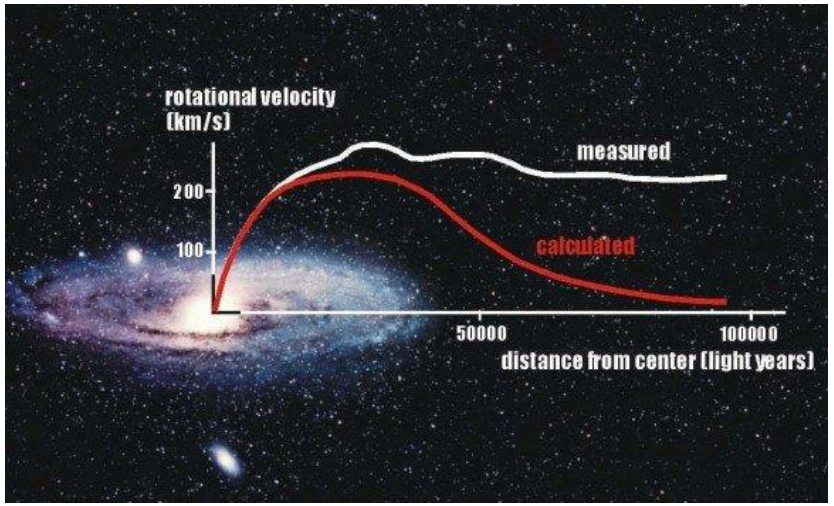




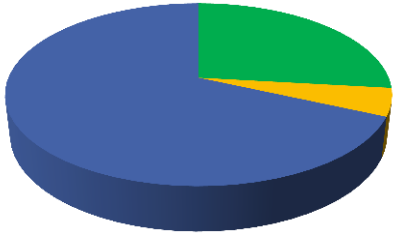



Physical evidence for Dark Matter

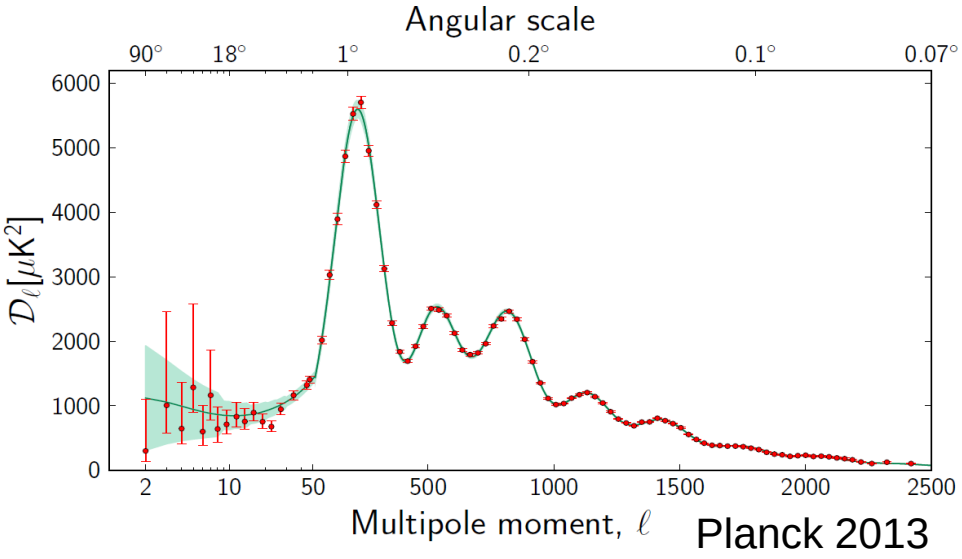


1 Mpc ≈ 3.26 Mly





- Dark Matter: 26.8%
- Ordinary Matter: 4.9%
- Dark Energy: 68.3%



Planck 2013

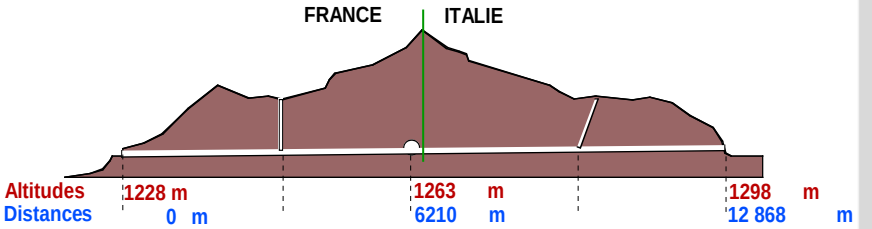
Challenging direct detection of Dark Matter

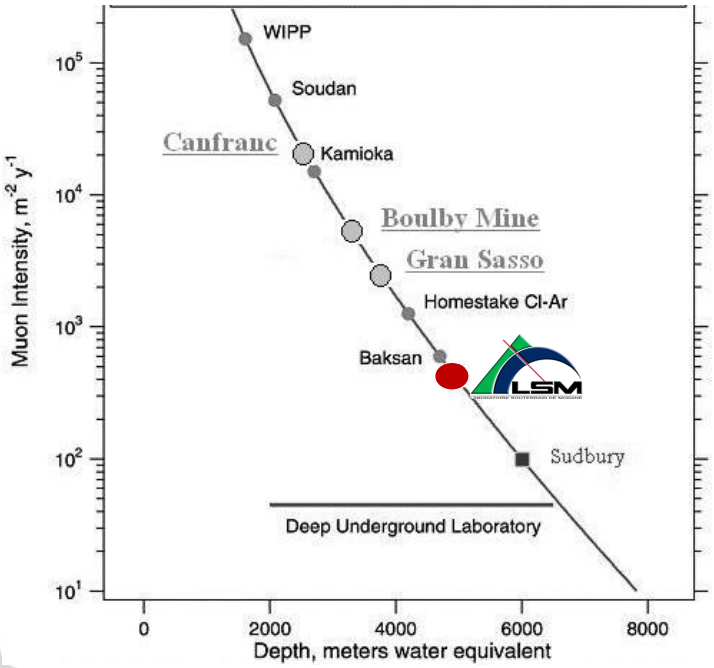
Low event rate: <1 evt/kg/year

Small energy deposit: ~ 10 keV

Background events by: β, γ, n

μ - induced background





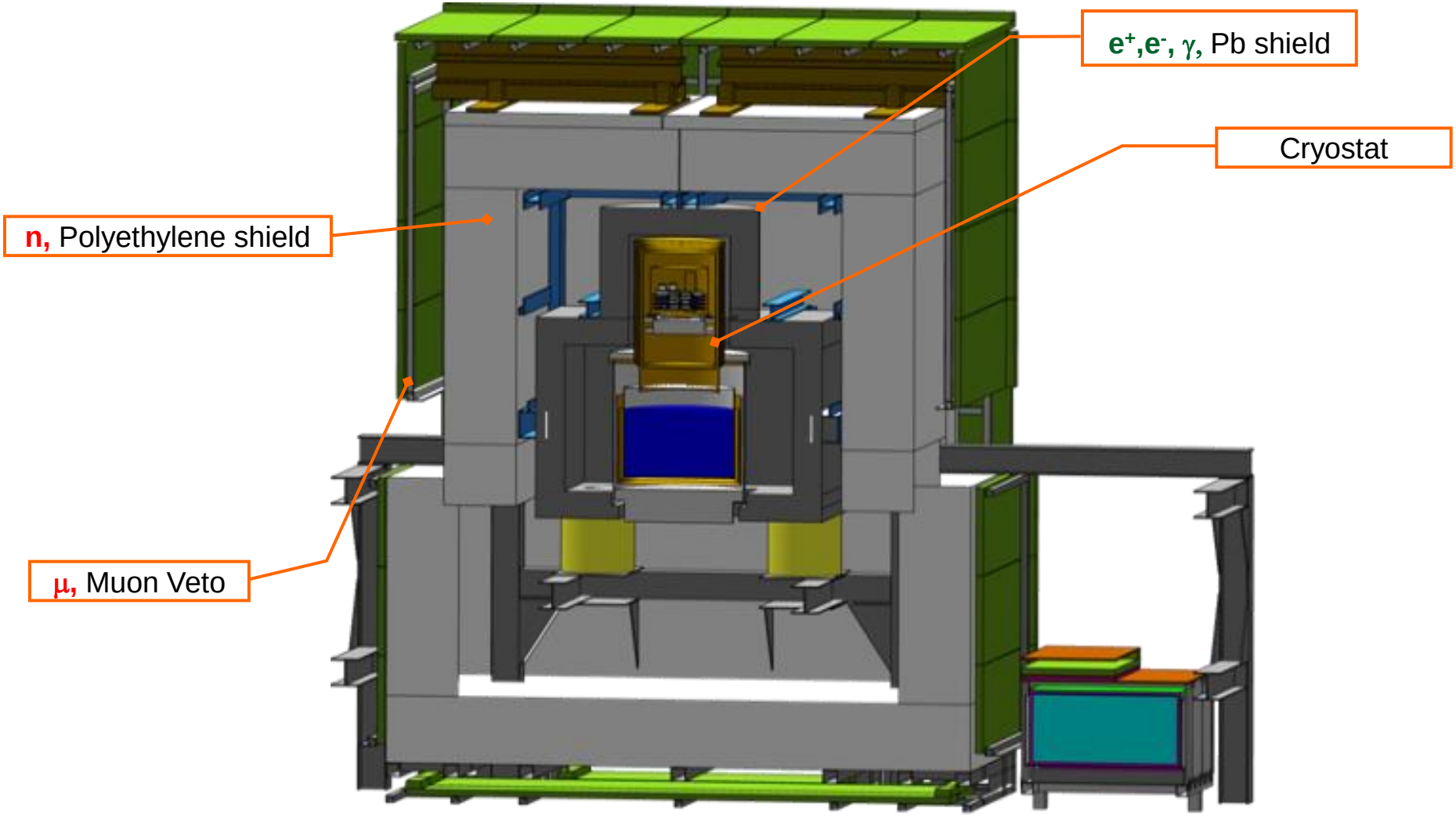
Laboratoire Souterrain de Modane (LSM) in Fréjus Tunnel

4800 mwe depth: ~5 muon/day/m^2

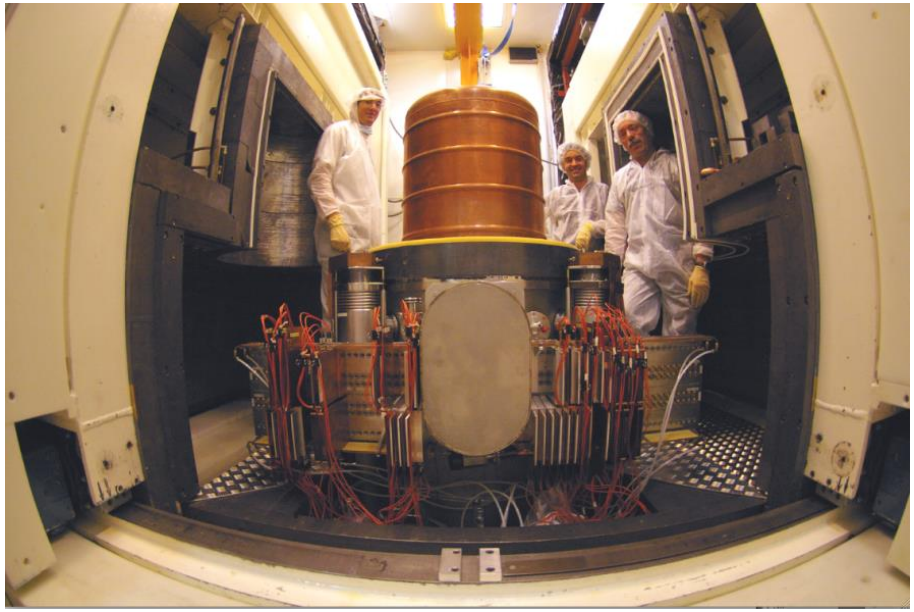
10^{-6} neutrons/cm^2/s (>1MeV)

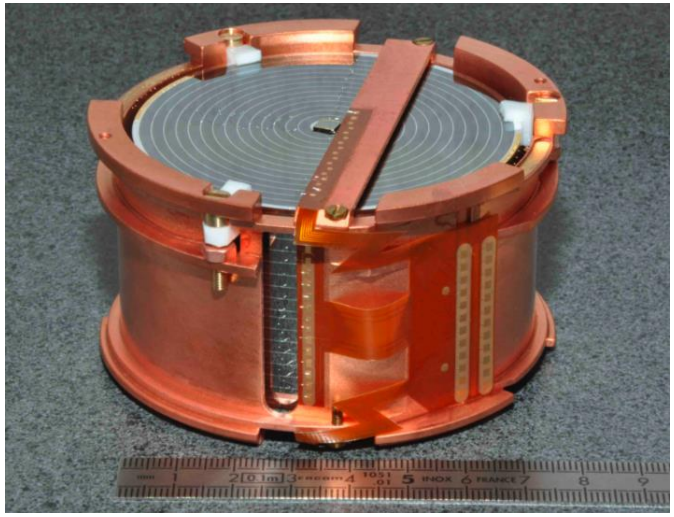
Deradonized air facility (~10 Bq/m^3 → ~30 mBq/m^3)

EDELWEISS schematic setup

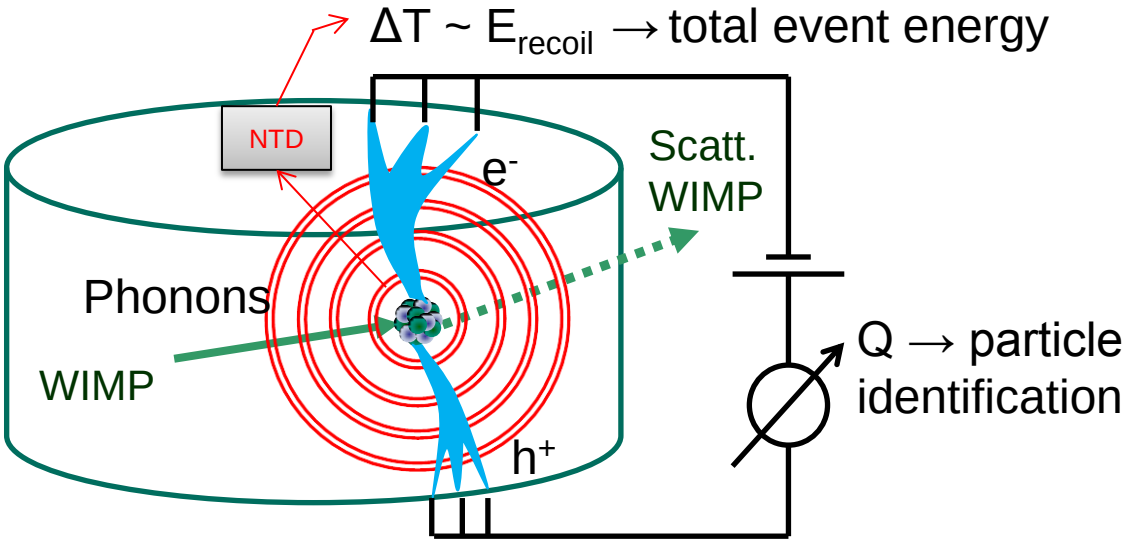


EDELWEISS setup



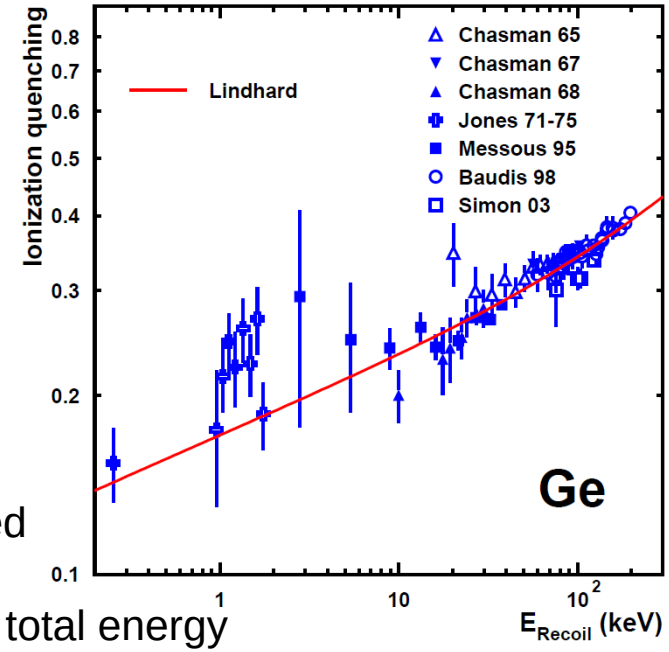


Cryogenic Germanium bolometers

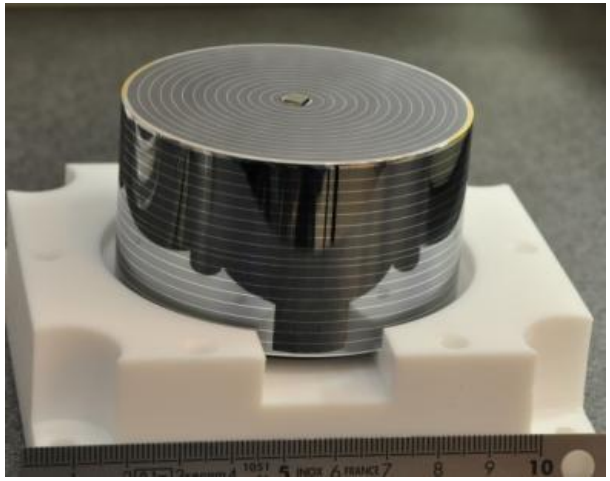


Ge detector at 18 mK

Challenges:
Low event rate: <1 evt/kg/year
Small energy deposit: ~ 10 keV
Background events by: β, γ, n
μ – induced background



A. Benoit et al.
NIMA 577 (2007) 558



Simultaneous measurement of heat and ionization

Neutron Transmutation Doped (NTD) thermal sensor calorimetric measurement of total energy

Ionization yield:
$Q = E_{Ion}/E_{Rec}$ nuclear recoils have ~1/3 Q of e^- recoils

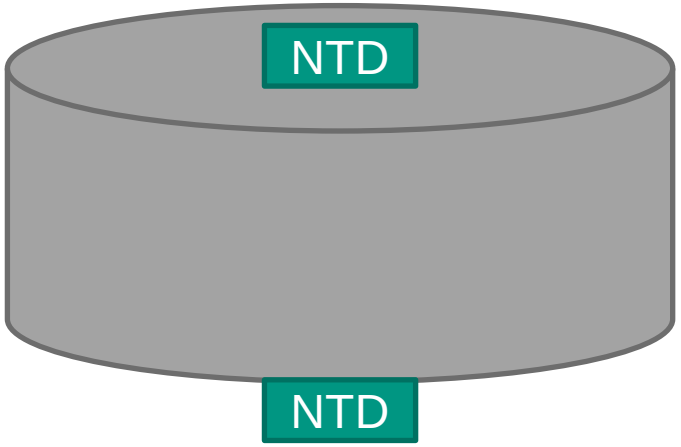
Signal characteristics: heat

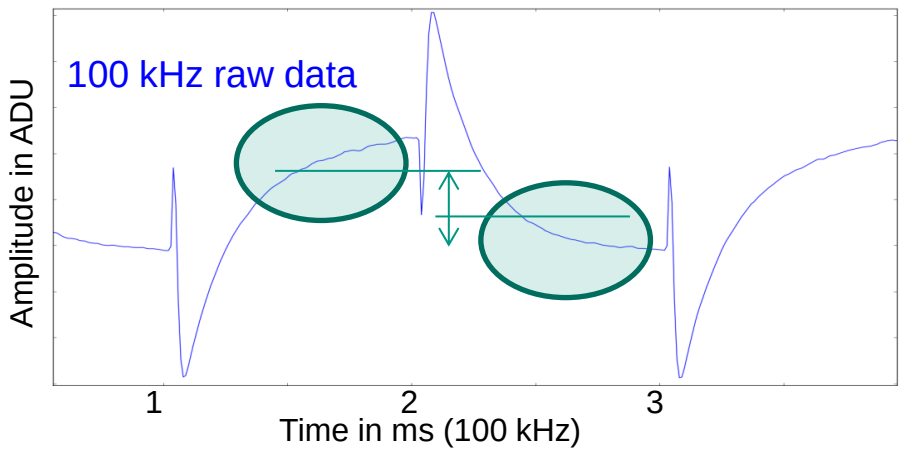
2 heat channels from NTD thermal sensors:

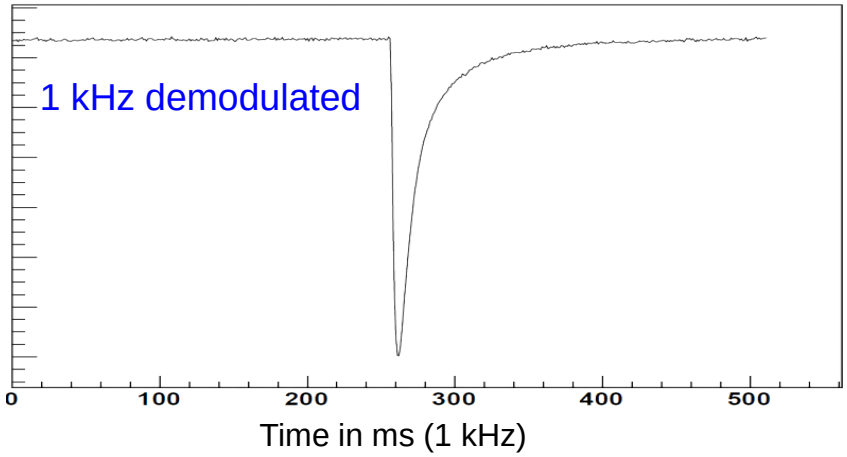
rise time ~1 ms
decay time ~200 ms

for a 10 keV event: $\Delta T \approx 1\ \mu K \triangleq 1\ \mu V$

demodulation: down sampling to 1 kHz







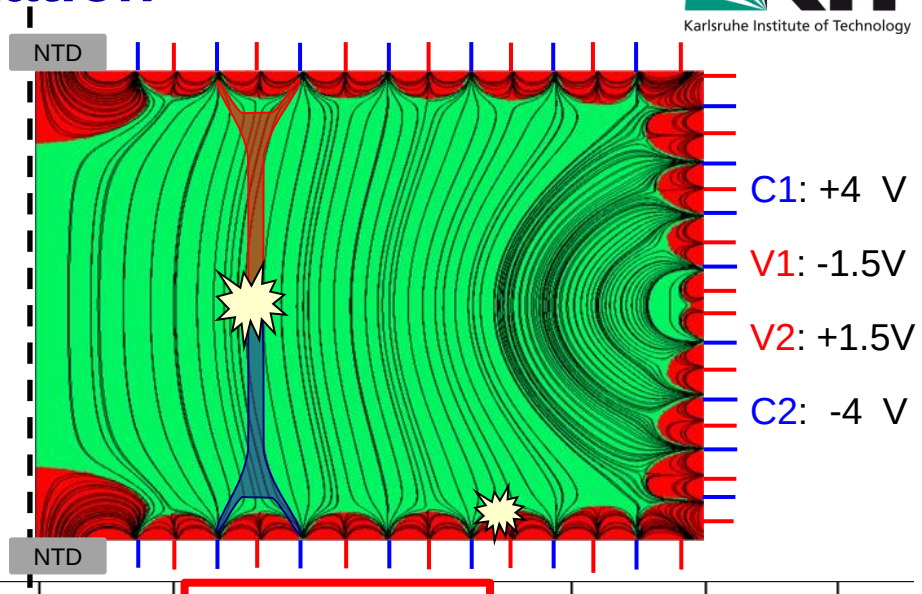
Signal characteristics: ionization

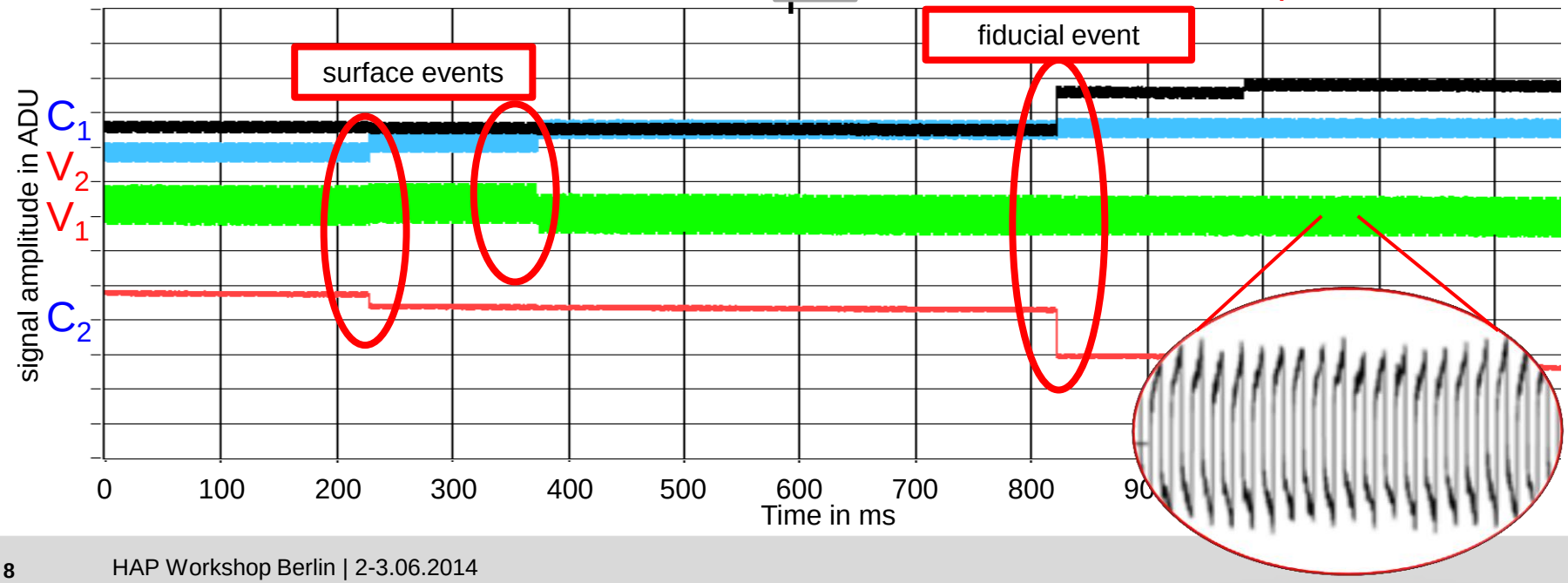
4 ionization channels per bolometer from interleaved ring electrodes:

rise time ~ 100 ns

for a 10 keV event: ΔV ≈ 4-5 µV
Sub – keV resolution

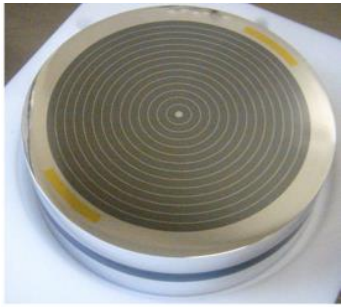
Readout at 100 kHz and 5 kHz

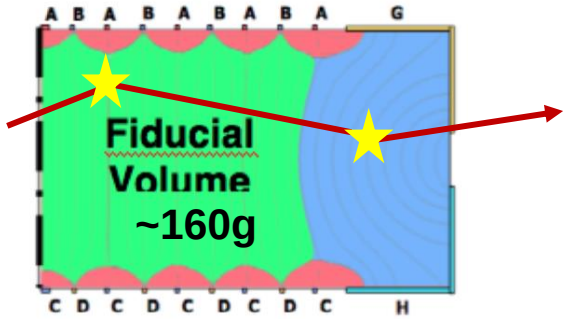


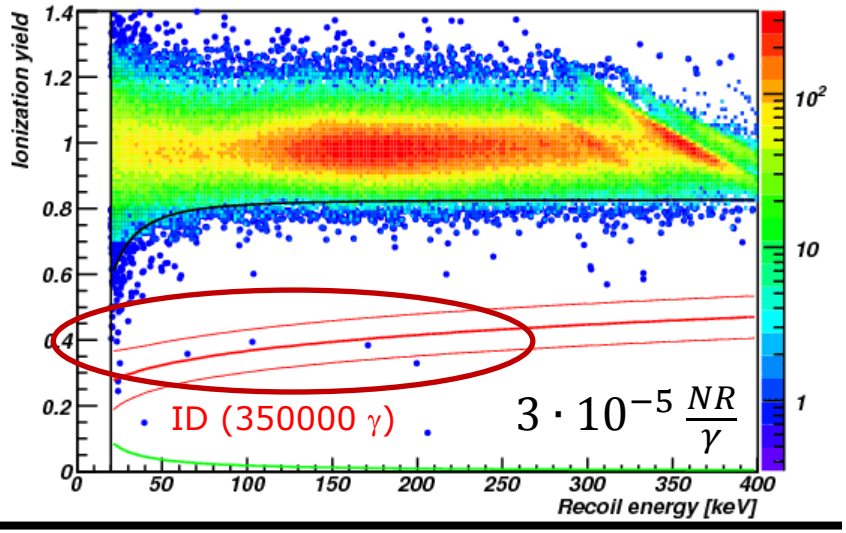


γ rejection power in EDELWEISS-III

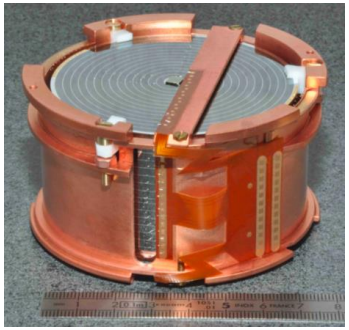
EDELWEISS-II
ID 400g with 10x **160g** fiducial mass

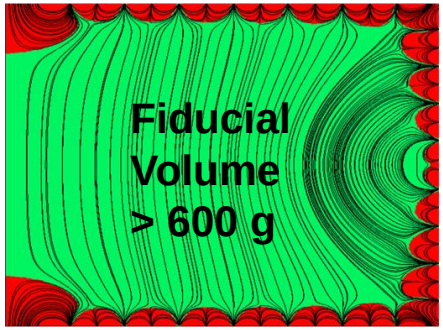


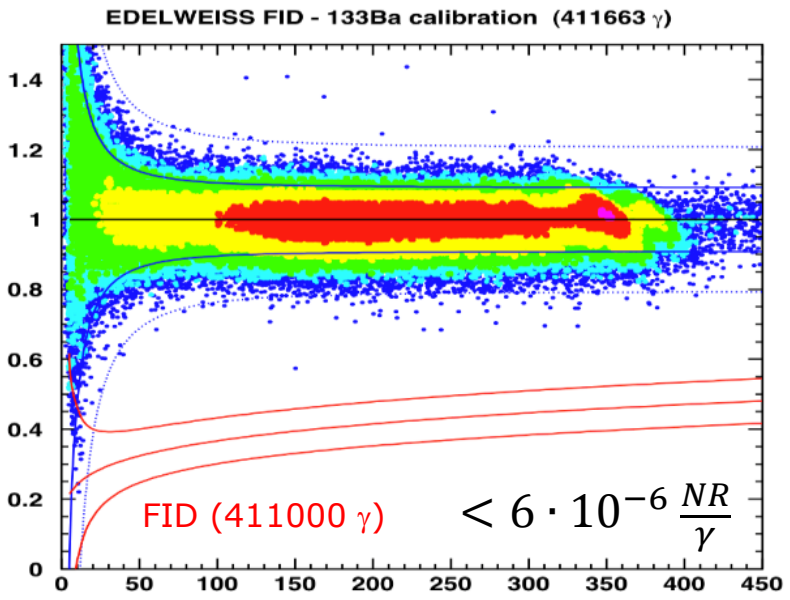




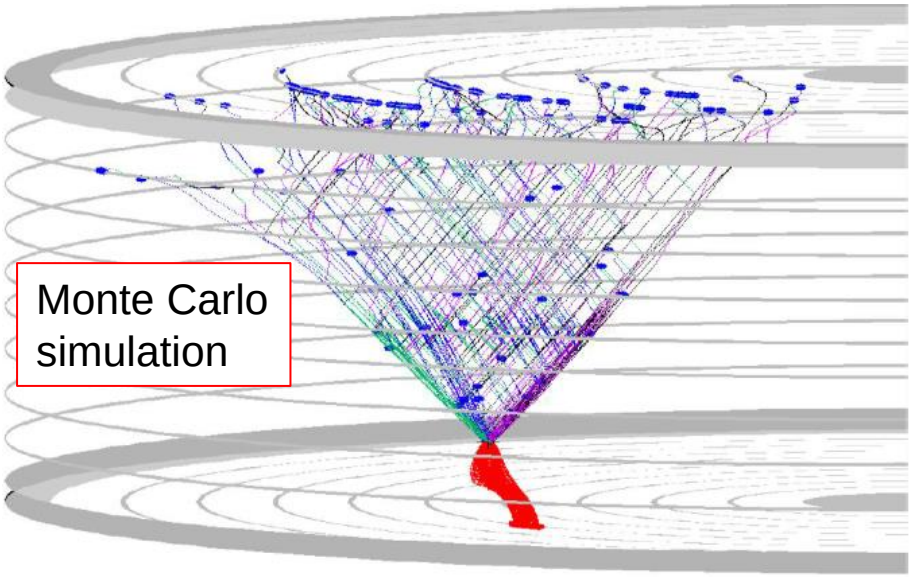
EDELWEISS-III
FID 800g with ~600g fiducial mass

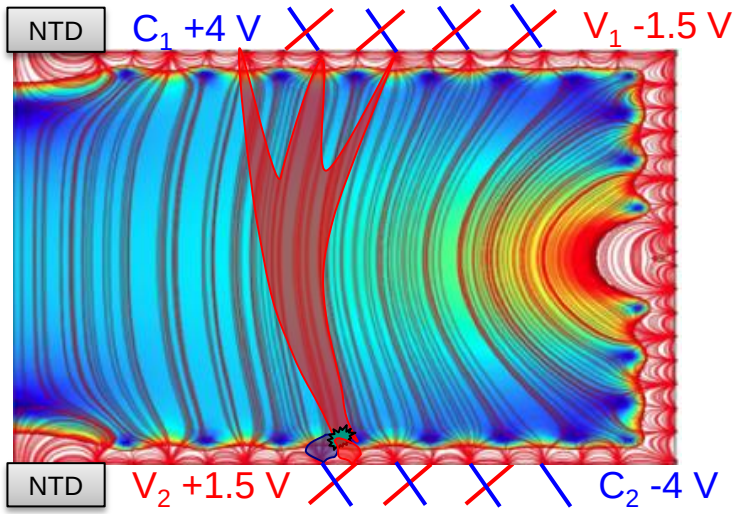


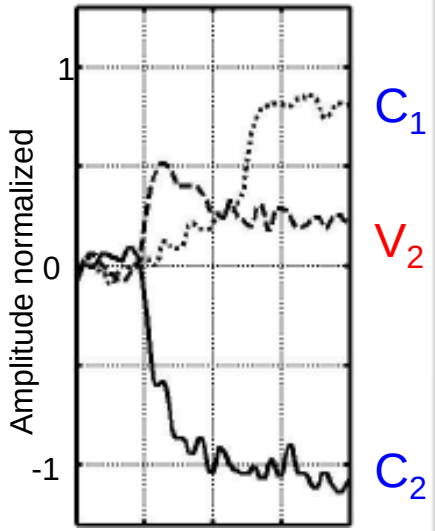




Additional information from time resolved ionization signals







Broniatowski, A. et al. PLB 681 (2009)

Additional spatial information on z-axis of bolometer

Improved understanding of charge migration

Identifying double scatter events

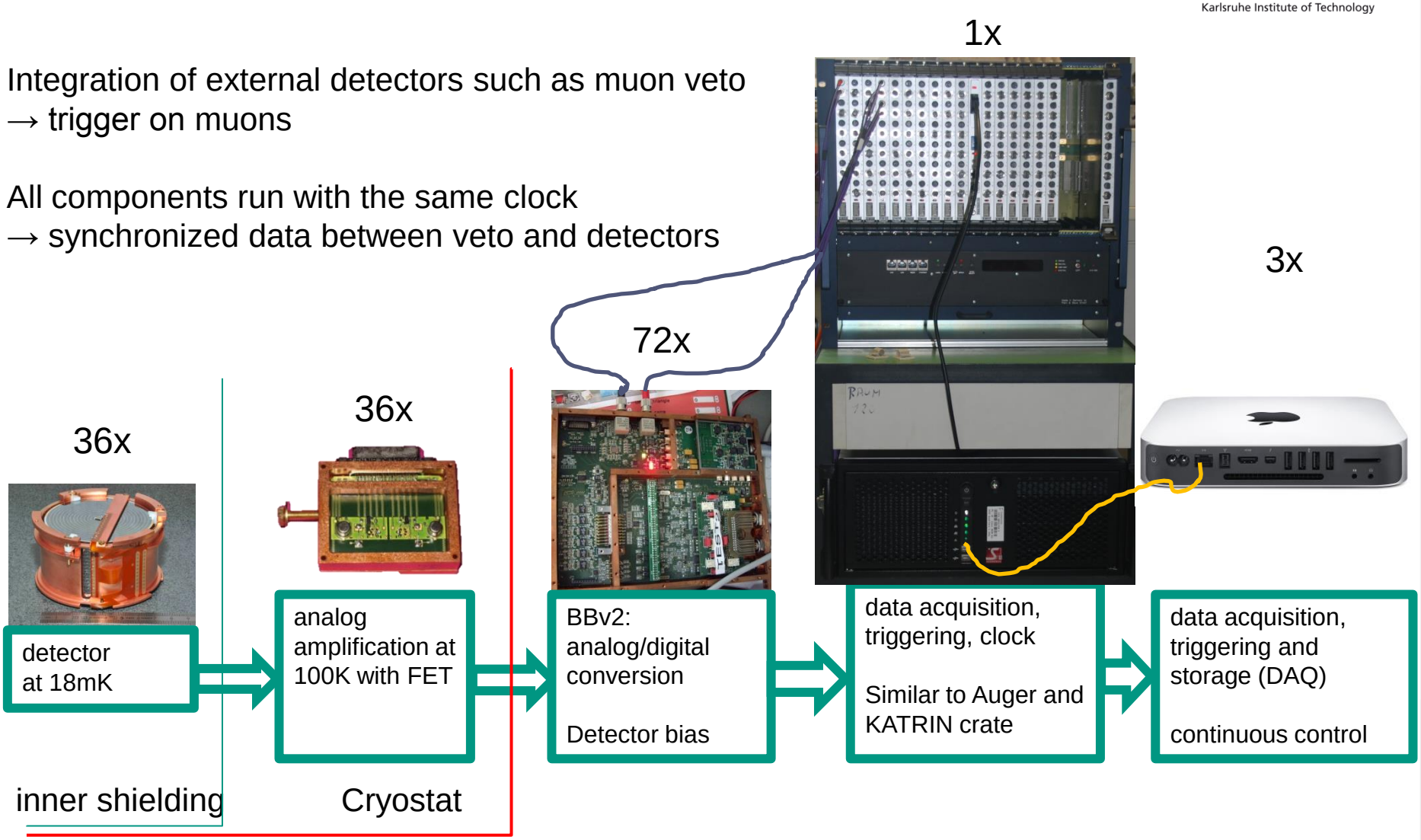
Surface event rejection

Event based readout needed for 40 MHz channel
→ Trigger on ionization channel

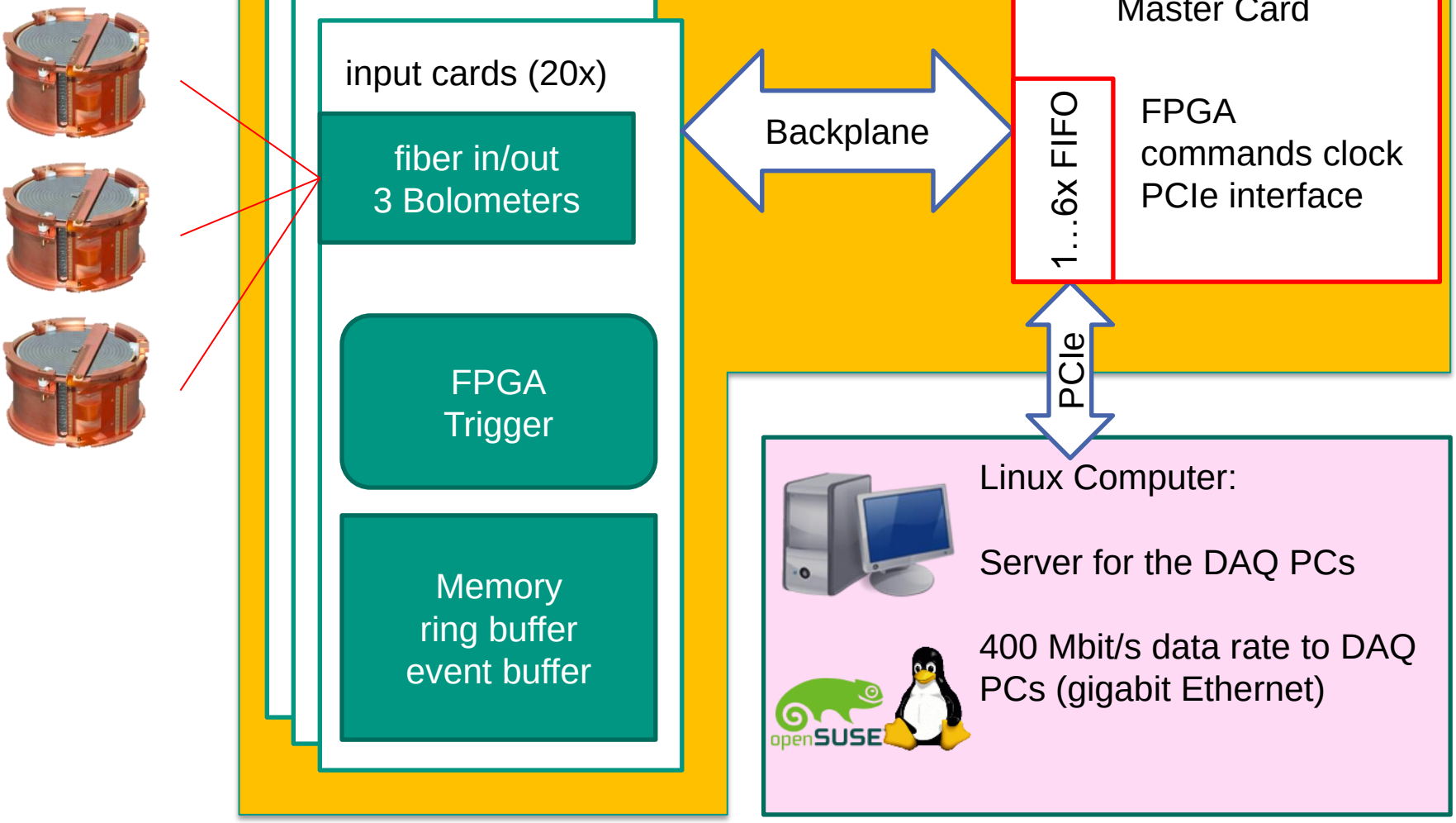
EDELWEISS-III DAQ system

Integration of external detectors such as muon veto
→ trigger on muons

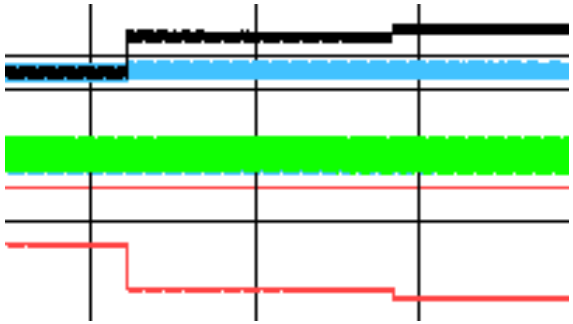
All components run with the same clock
→ synchronized data between veto and detectors



Principle of the digital DAQ

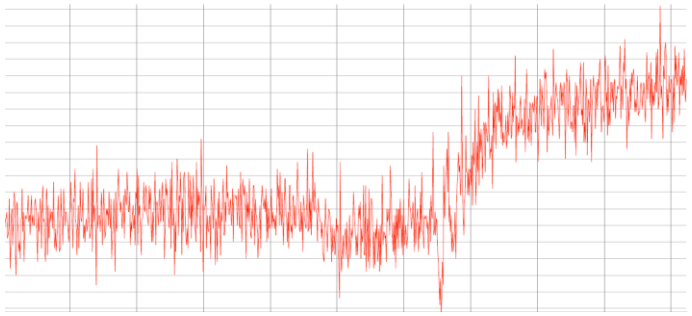


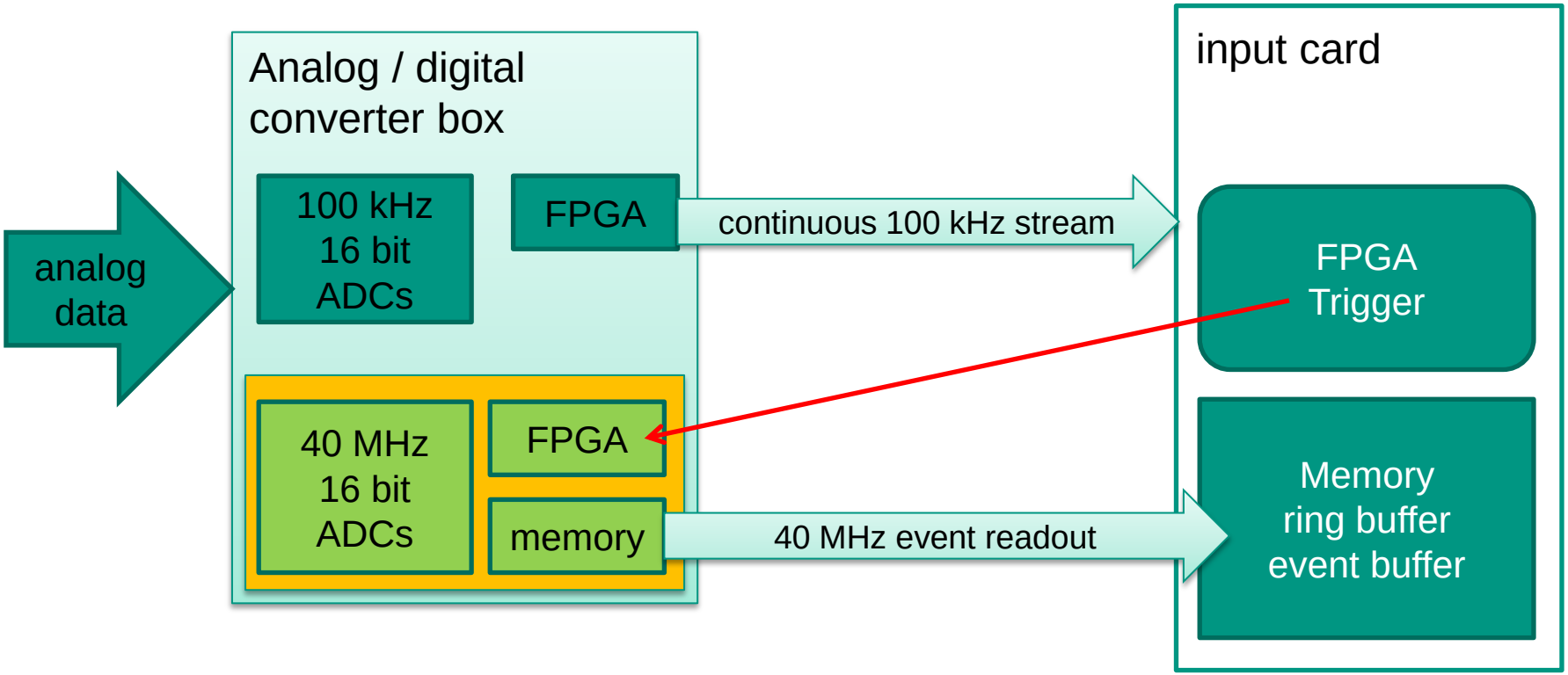
Trigger algorithm for time resolved channel



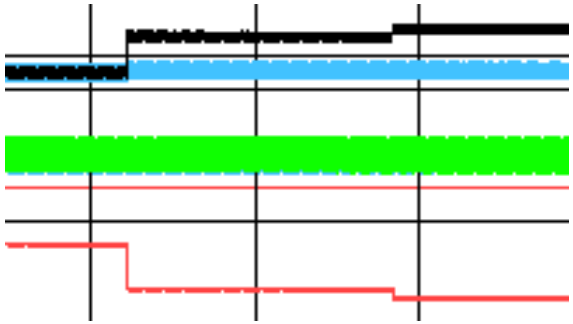
"slow" 100 kHz

"fast" 40 MHz



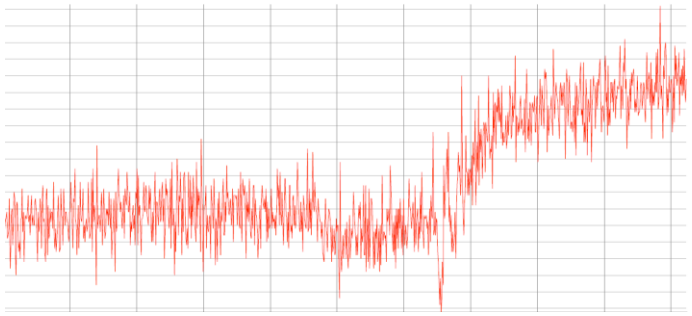


Trigger algorithm for time resolved channel



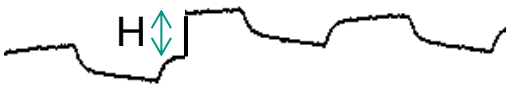
"slow" 100 kHz

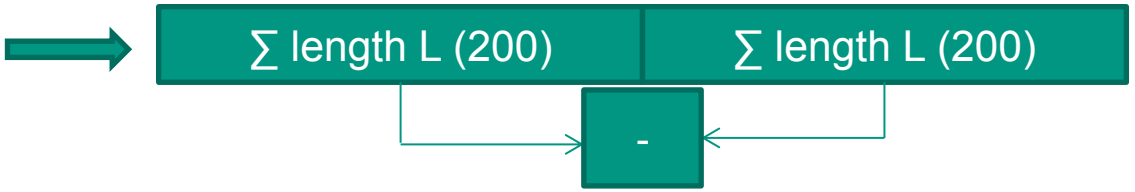
"fast" 40 MHz

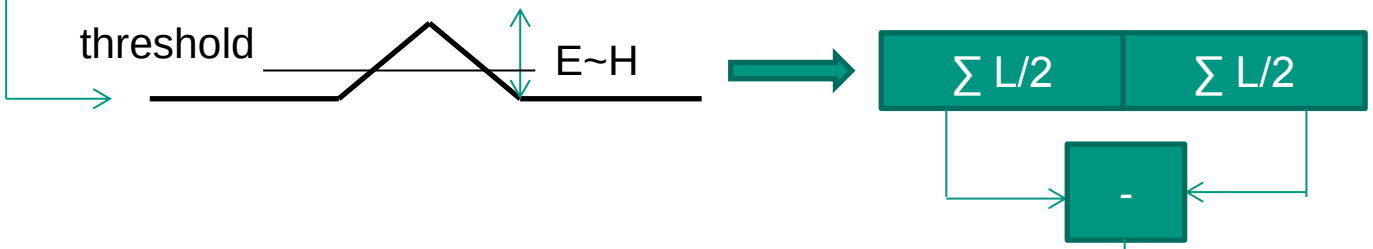


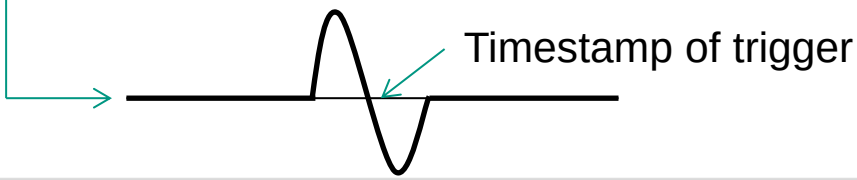
"cascaded trapezoidal filter"

raw 100 kHz data stream

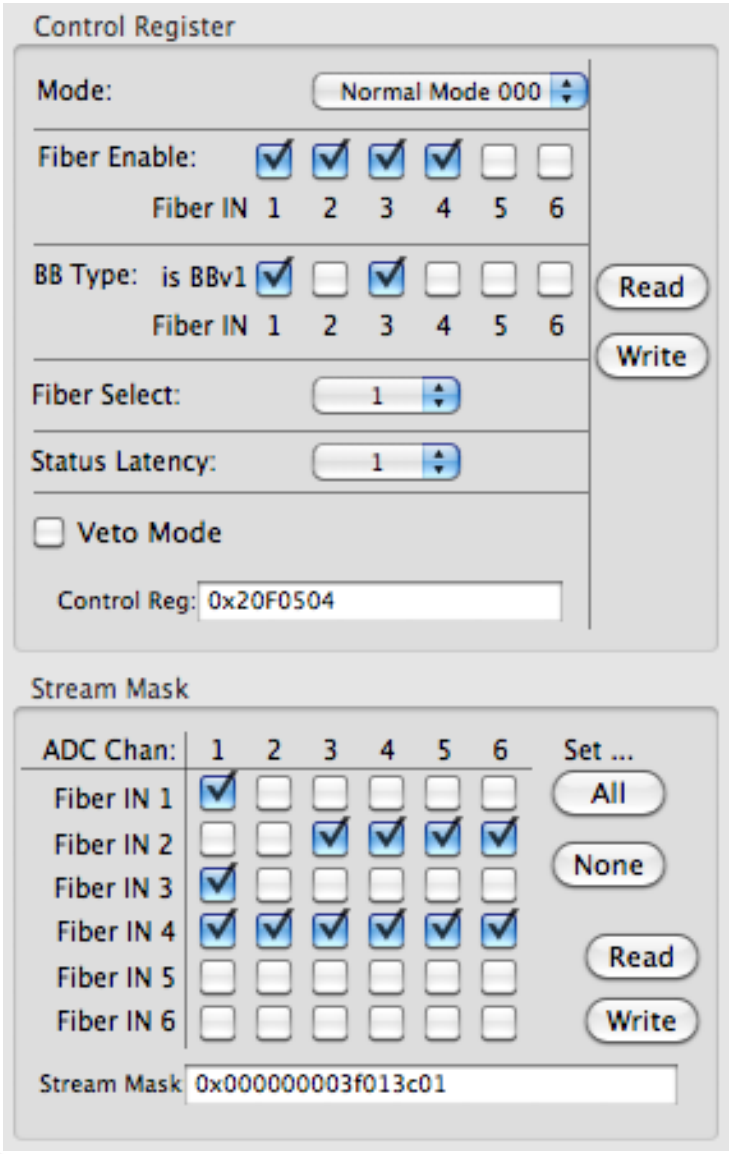








ORCA based control



DAQ software for low-level hardware control/readout

High-level experimental configuration and run control

ORCA interface is under development, new functions are implemented at this time. [Till Bergmann]

ORCA ROOT interface

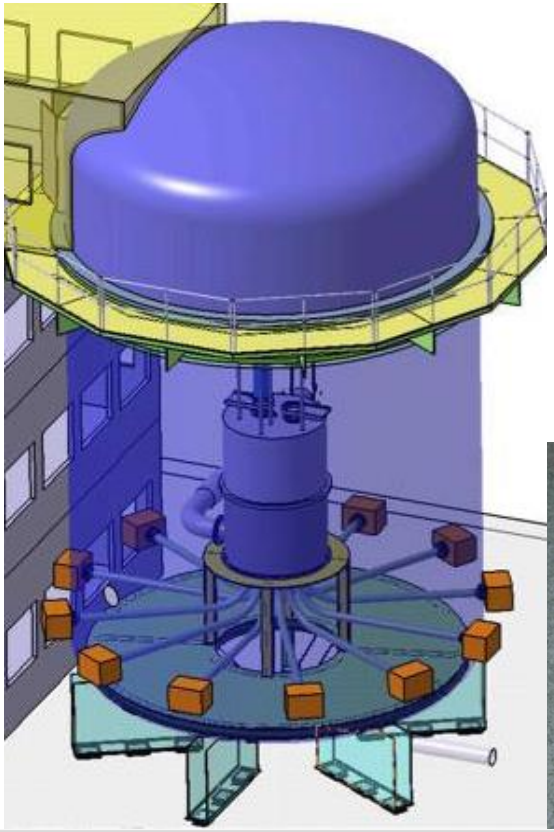
Other experiments using ORCA:
e.g. SNO, Majorana, KATRIN, EXO

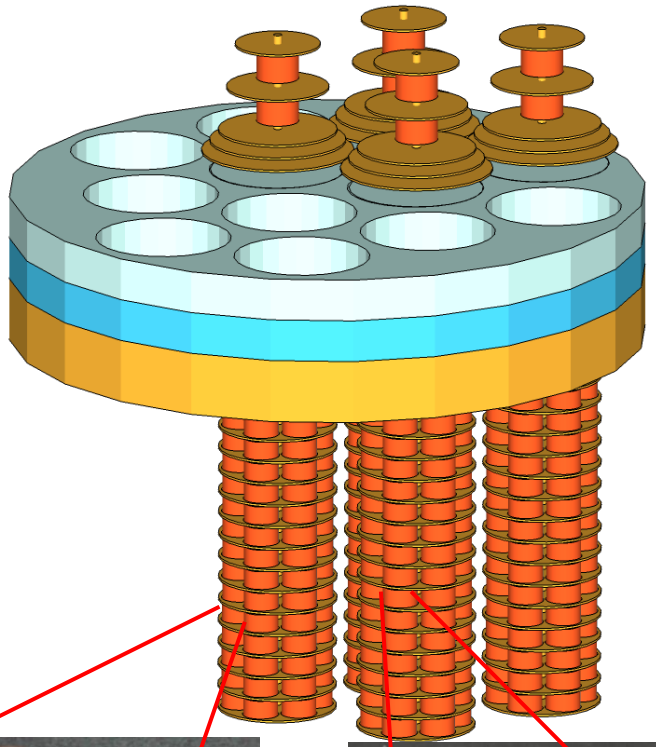
http://orca.physics.unc.edu

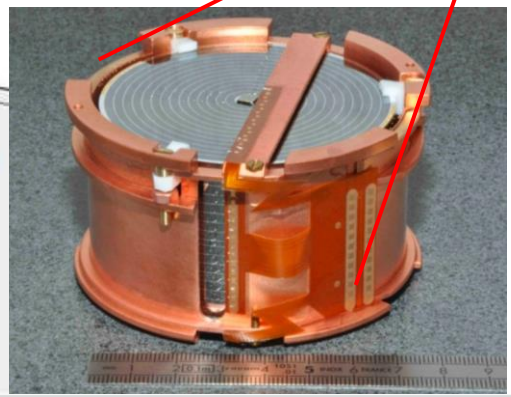
Future experiment: EURECA

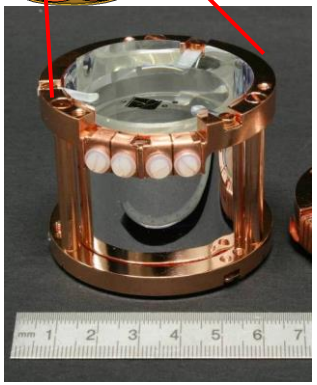
More detectors = more readout channels
Combined use of $CaWO_4$ and Ge detectors
(CRESST-, EDELWEISS-Type)

Cooperation with SuperCDMS
Design of a common cryogenic facility at SNOLAB



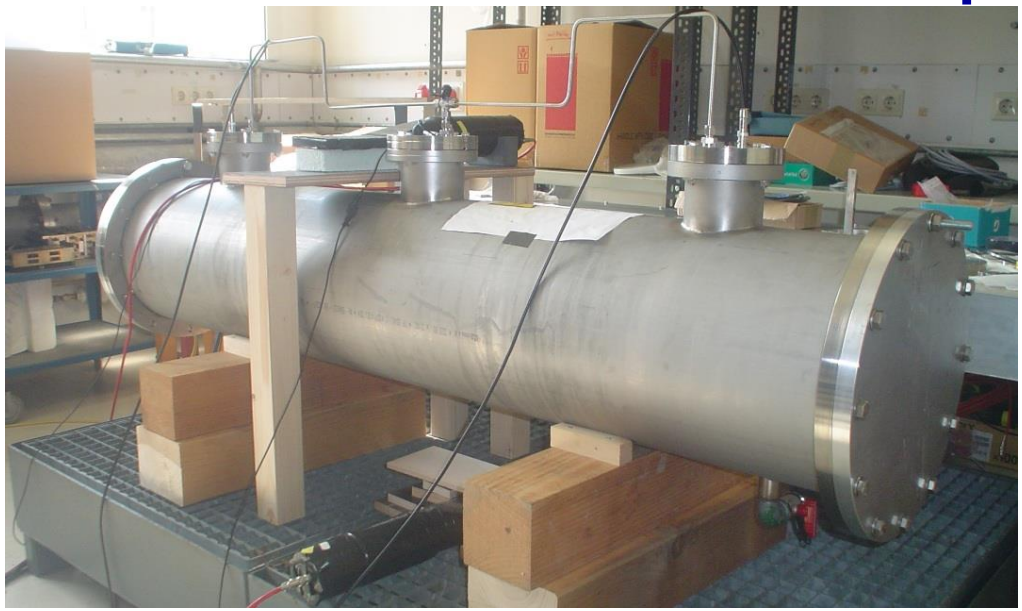






EURECA CDR
Physics of the Dark Universe, **3**, (2014) 41

Water-Cherenkov detector as μ-veto



Prototype for Active Muon Veto

Water tank containing pure water

Two encapsulated PMTs inside at the end plates

Diffuser ball containing LED or end of fibre optic

Cherenkov light from through-going muons

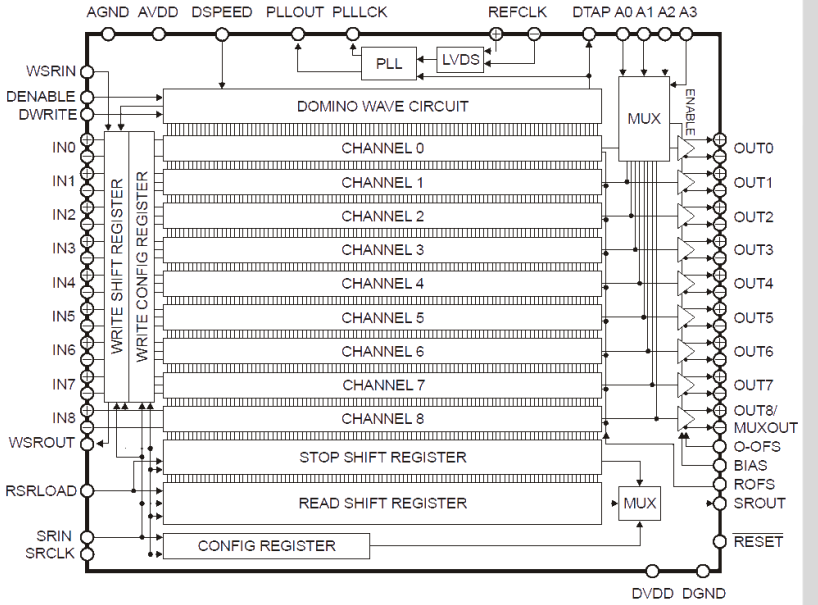
DRS4 and µ-TCA based readout

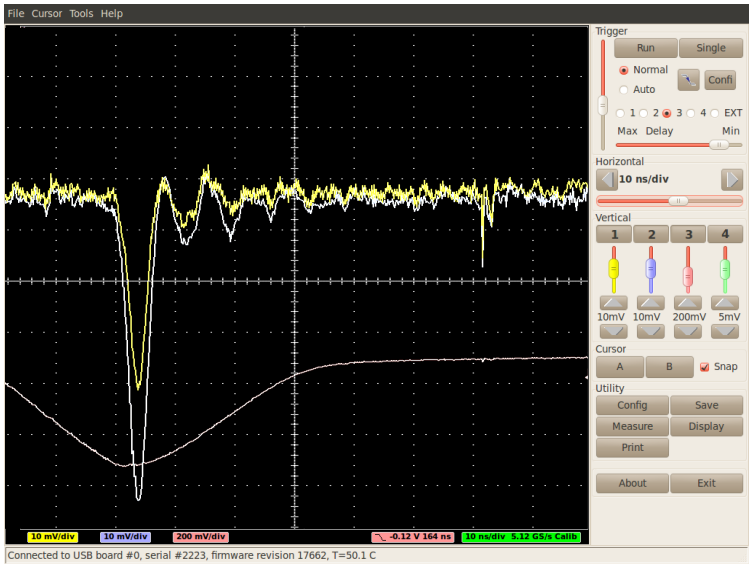
DRS4 switched capacitor array evaluation board

- High speed (5 GHz), 12-bit resolution, high channel density (8 channels on 5x5 mm)
- Low power (10-40 mW/channel)
- Low cost (~ €10/channel)

µ-TCA RTM card

- Based on DRS4 chips
- 16 channels/card, 6 cards needed for EURECA muon veto
- Prototype card produced, currently tested





µTCA DAQ Crate

Crate Power Modules:
- µTCA Carrier Hub (MCH)

AMC board:
- Universal board
- Processor
- DSP
- FPGA

Rear Transition Module (RTM):
- Rear I/Os
- Signal conditioning
- Custom Adaption

Conclusion

EDELWEISS-III DAQ:

- 240 channels at 100 kHz
- Trigger on µ
- Stream readout of all channels
- Event based readout of 40 MHz ionization channels
- Total data rate: 400 Mbit/s (possible with Ethernet)

EURECA DAQ:

Same but

- ~ 5000 channels at 10 MHz, 16 bit
- Need data reduction by hardware trigger
- 5 TB/month