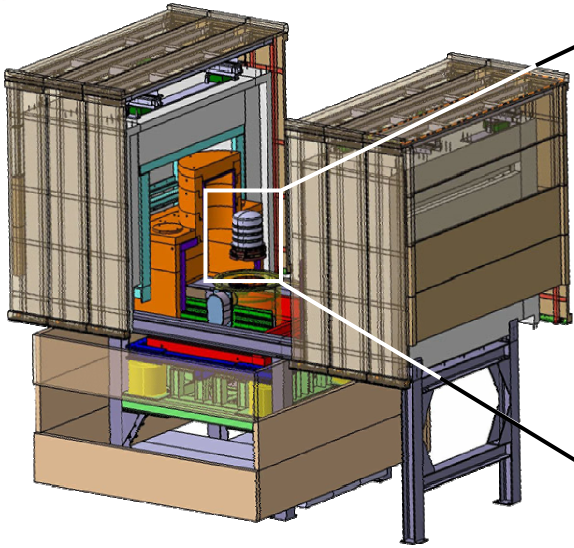
Investigation of the neutron background within the EDELWEISS dark matter search

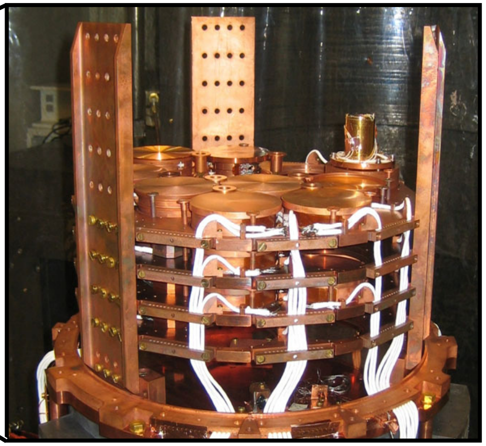
SFB-TR27
Project B1

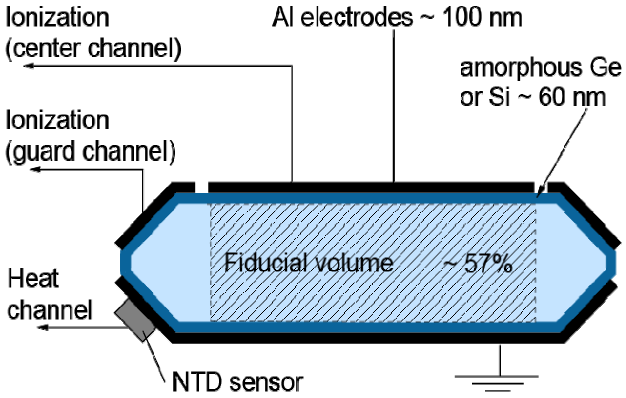
- Introduction/Motivation
- Principle of μ-n counter
- Scintillator stability
- Neutron measurements
- Outlook
- Summary

KIT Karlsruhe Institute of Technology
HELMHOLTZ GEMEINSCHAFT
Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft

EDELWEISS-II principle

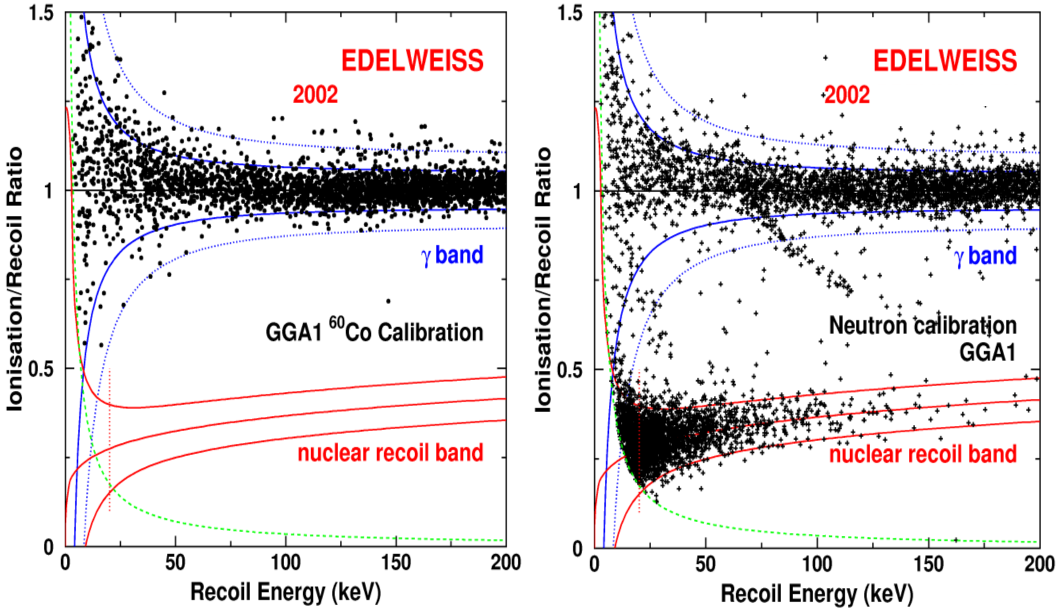




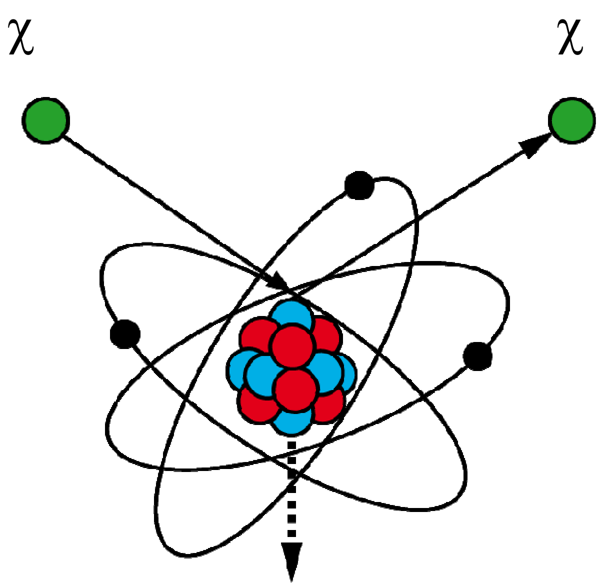


- **Simultaneous measurement**
  - **Heat** @ 17 mK with Ge/NTD thermometer
  - **Ionization** @ few V/cm with Al electrodes
- **Evt by evt identification** of the recoil by ratio $Q=E_{ionization}/E_{recoil}$
  - **Q=1 for electronic recoil**
  - **Q≈0.3 for nuclear recoil**

Discrimination γ/n > 99.9% for E_r> 15keV

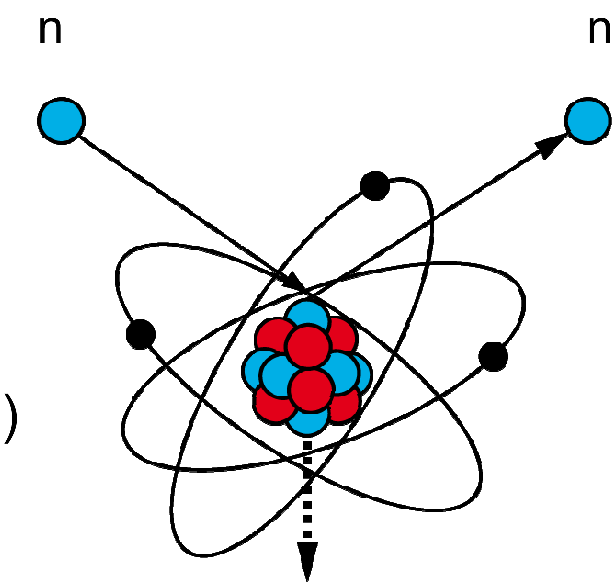


n's as background for direct DM search



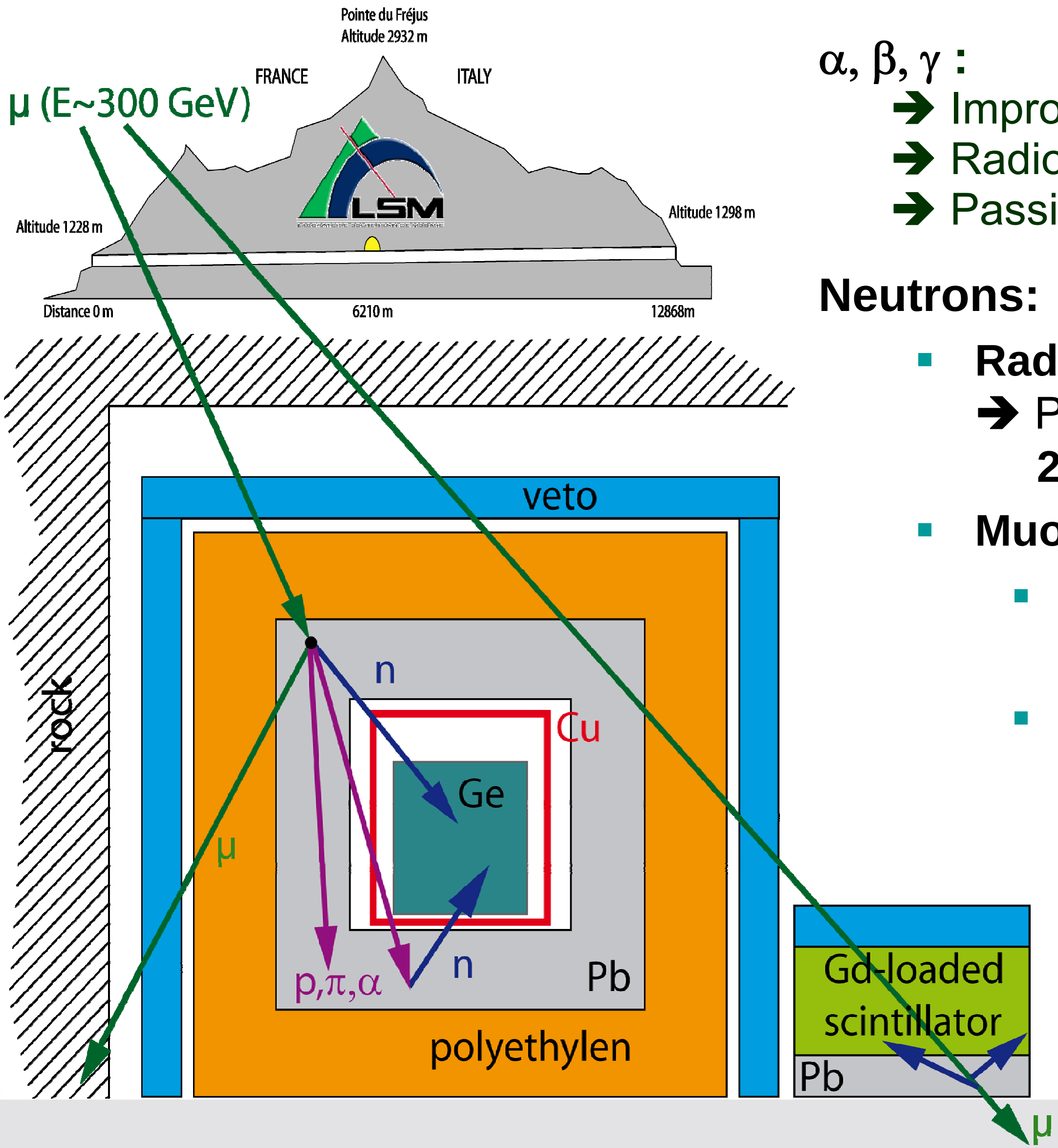
$v(\chi) \sim 300$km/s
$m(\chi) \sim 70$GeV
→ $E_{rec,\,max} \sim 35$ keV

elastic scattering off nuclei (e.g. ^{72}Ge)



$E_{rec,\,max} \sim 35$ keV
→ $E(n) \sim 0.6$MeV

EDELWEISS-II background



α, β, γ :

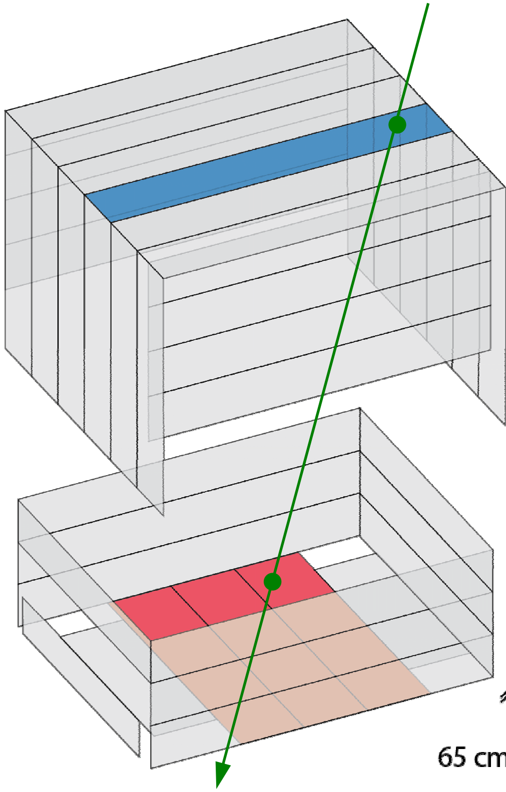
➔ Improvement of detector technology;
➔ Radiopurity of the materials;
➔ Passive shielding;

Neutrons:

- **Radioactivity** in the surrounding
  ➔ Passive shielding:
  20cm Pb + **50cm PE** shielding
- **Muon induced neutrons** produced :
  - In the detector material
    ➔ active **μ**-vetoing + Simulations;
  - In the surrounding rock (high-E **n**!)
    ➔ Simulations;

Need explicit μ-n coincidence measurement!

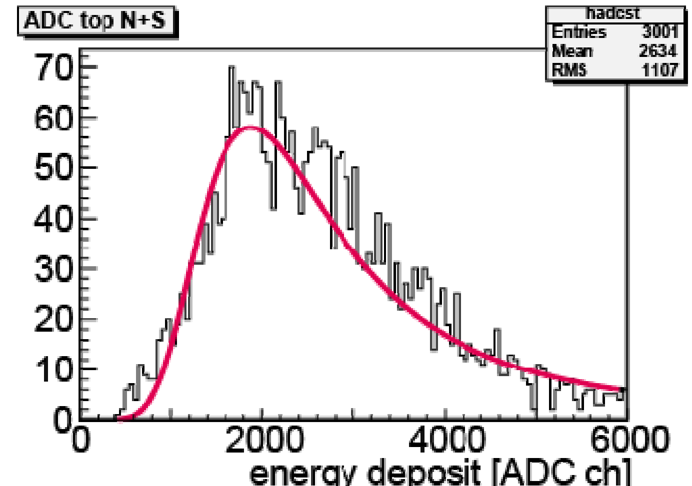
EDELWEIS-II muon veto system

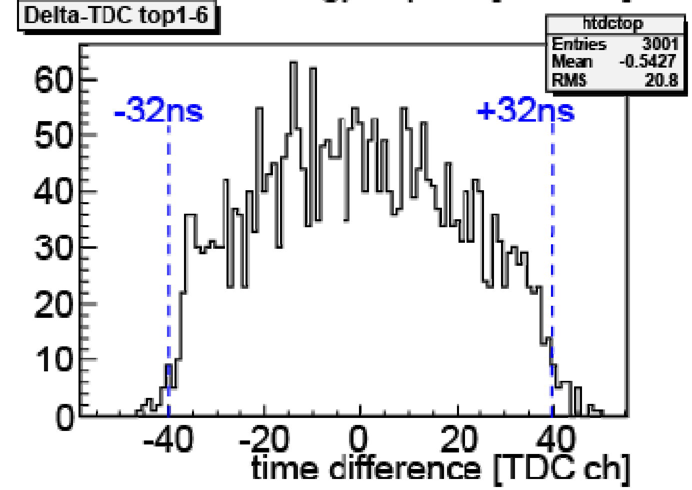


Muon candidates:

Energy deposit in two modules, e.g.

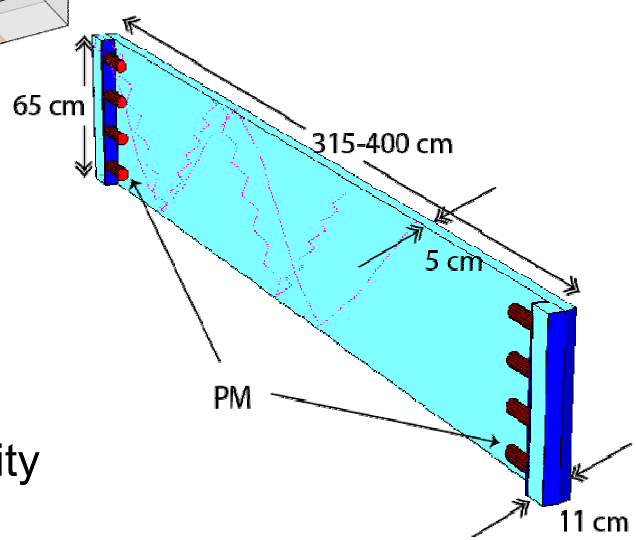
coincidence between one module of Top side and lower level (Niveau 0)





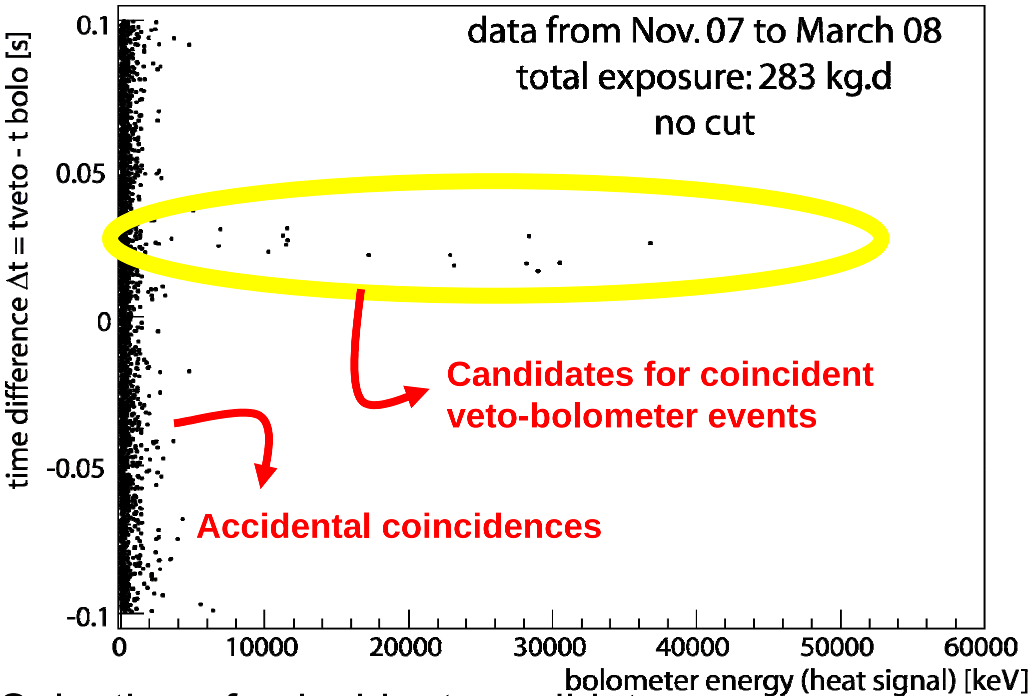
42 modules
covering 100 m^2
>98% coverage
energy, timing

→μ tracking capability

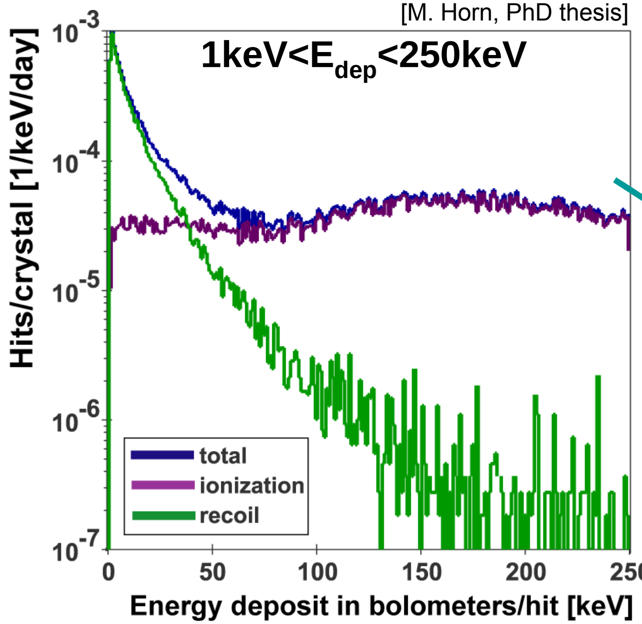


Coincidences in μ-veto and Ge bolometers

[A. Chantelauze, PhD thesis]



[M. Horn, PhD thesis]



Geant 4 simulation of **μ**-induced Ge-hits

Selection of coincident candidates:

- > 1 veto module hit
- 15 ms < Δt < 35 ms

	E_{recoil} < 250 keV	E_{recoil} > 250 keV
measured events	16	28
expected accidentals	3.7 ± 0.2	2.9 ± 0.2
excess coincidences	12.3 ± 4.2	25.1 ± 5.5
signal/background	3.3 ± 1.4	8.7 ± 2.4

Expected from Geant4 simulation:
~0.03 events/kg.d

Measured:
0.04 events/kg.d

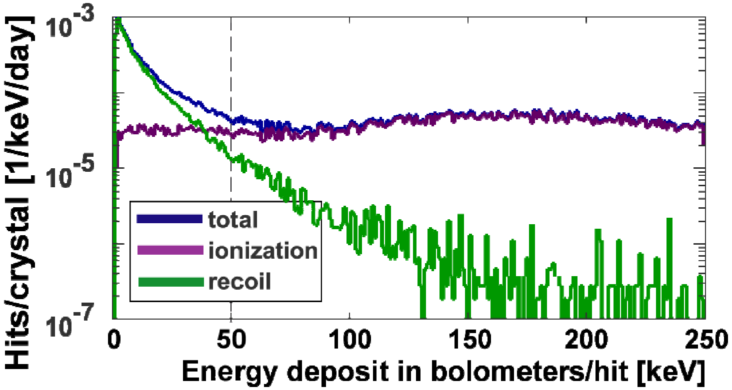
preliminary

Coincidences in μ-veto and Ge bolometers

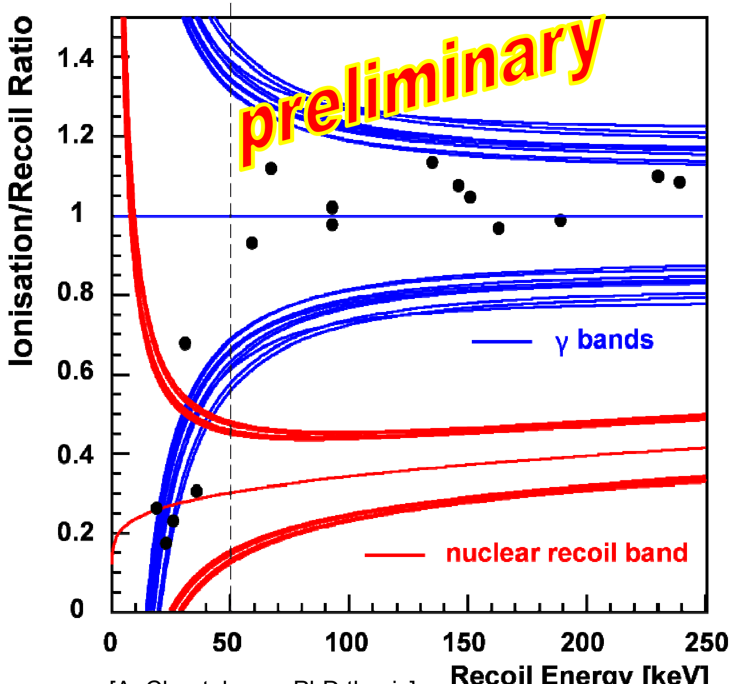
KIT Karlsruhe Institute of Technology

μ-induced n´s?

[M. Horn, PhD thesis]



Geant4

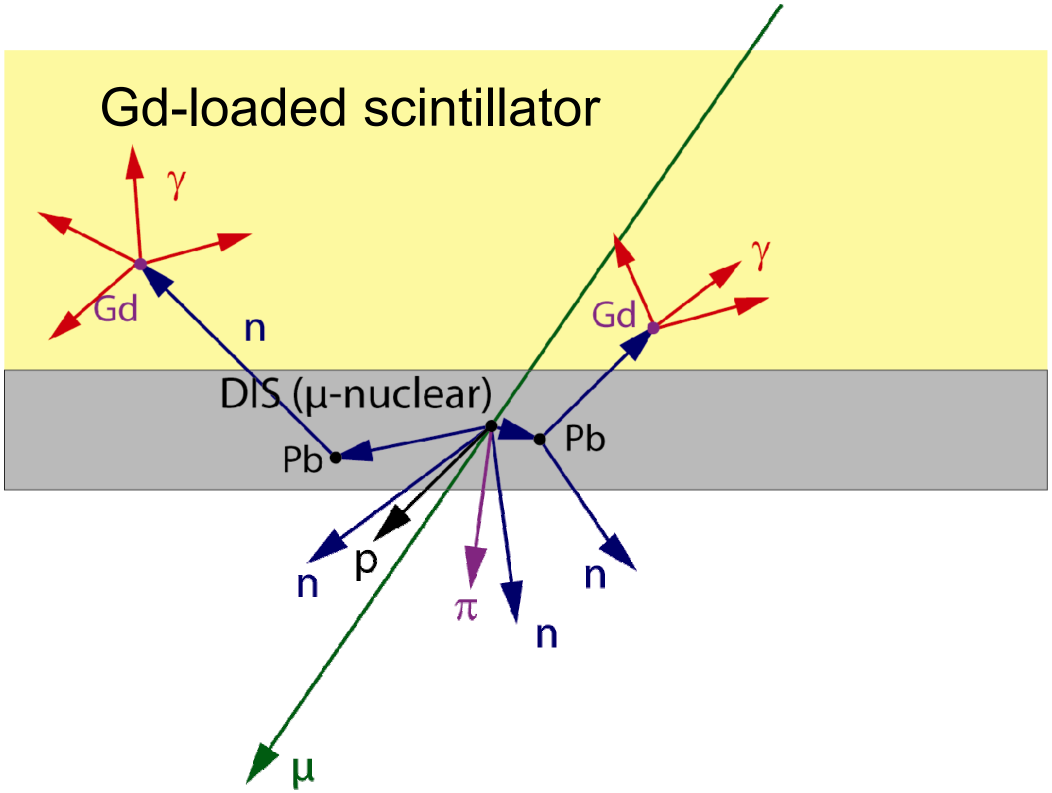


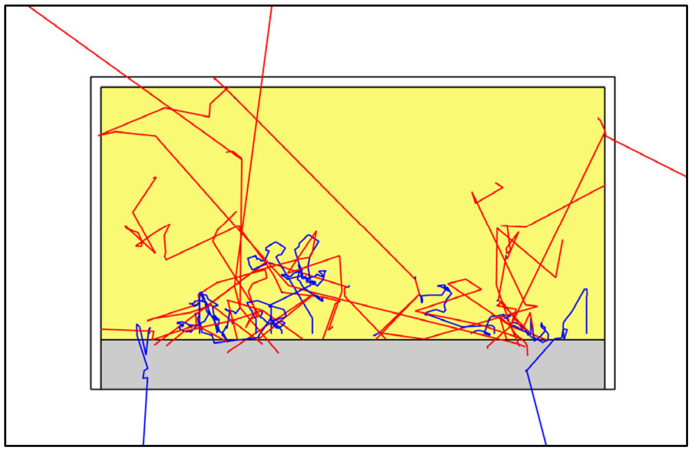
[A. Chantelauze, PhD thesis]

μ-veto coincident bolometer data

→most likely!

Neutron counter (NC) principle





Geant4

$^{157}Gd(\mathbf{n},\gamma)^{158}Gd$ $E\gamma$=8 MeV

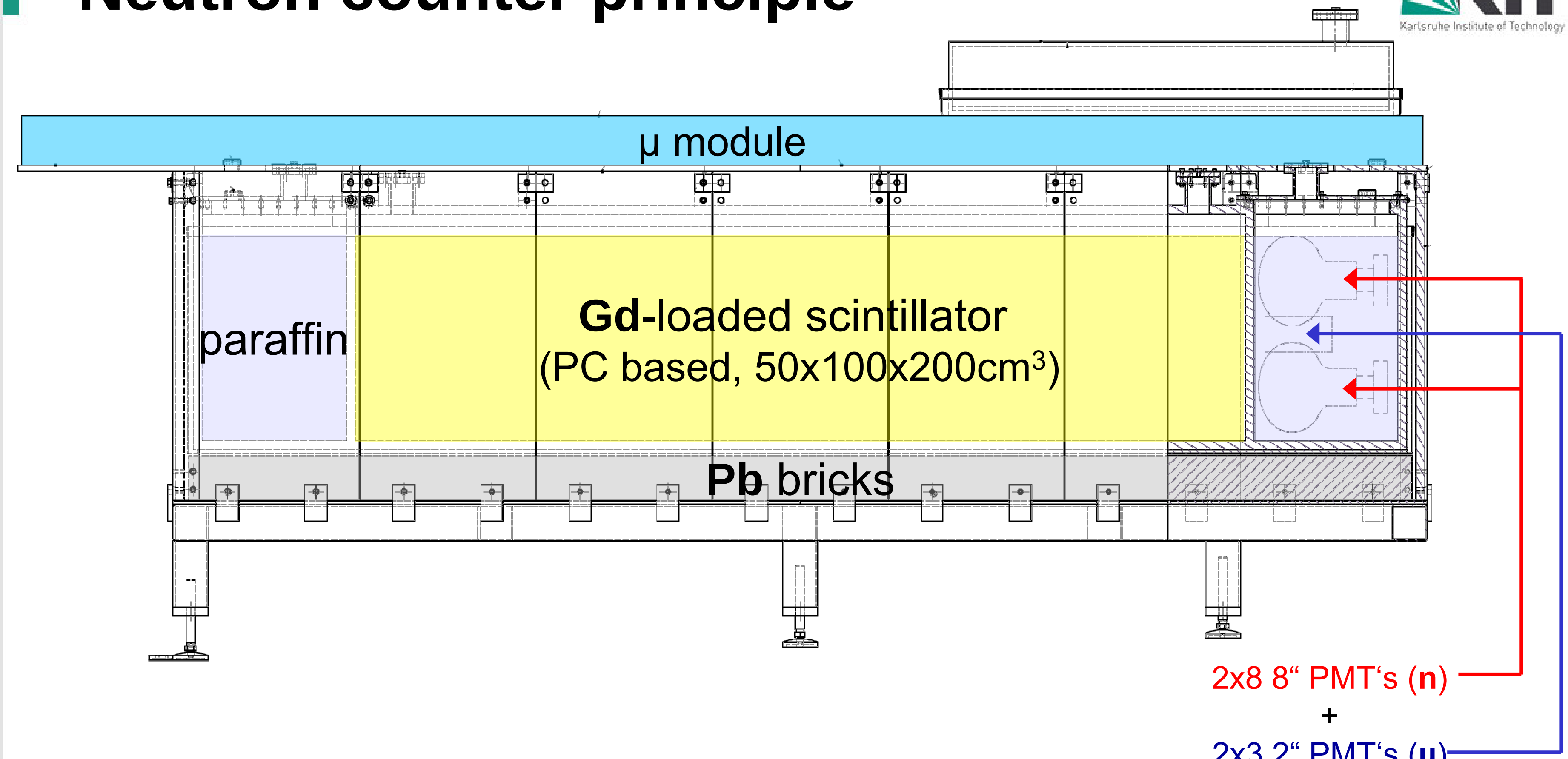
Signature: μ-n coincidence <u>or</u> multiple n's

Neutron count rate:

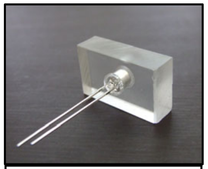
~1 /day (**μ**),

~8000 /day (radioactivity)

Neutron counter principle



- 1000l of Gd-loaded scintillator
- monitored by 8 LED´s
- 2x8 8" PMTs immersed in paraffin
- individual HV supply



8 LED's, λ=420 nm

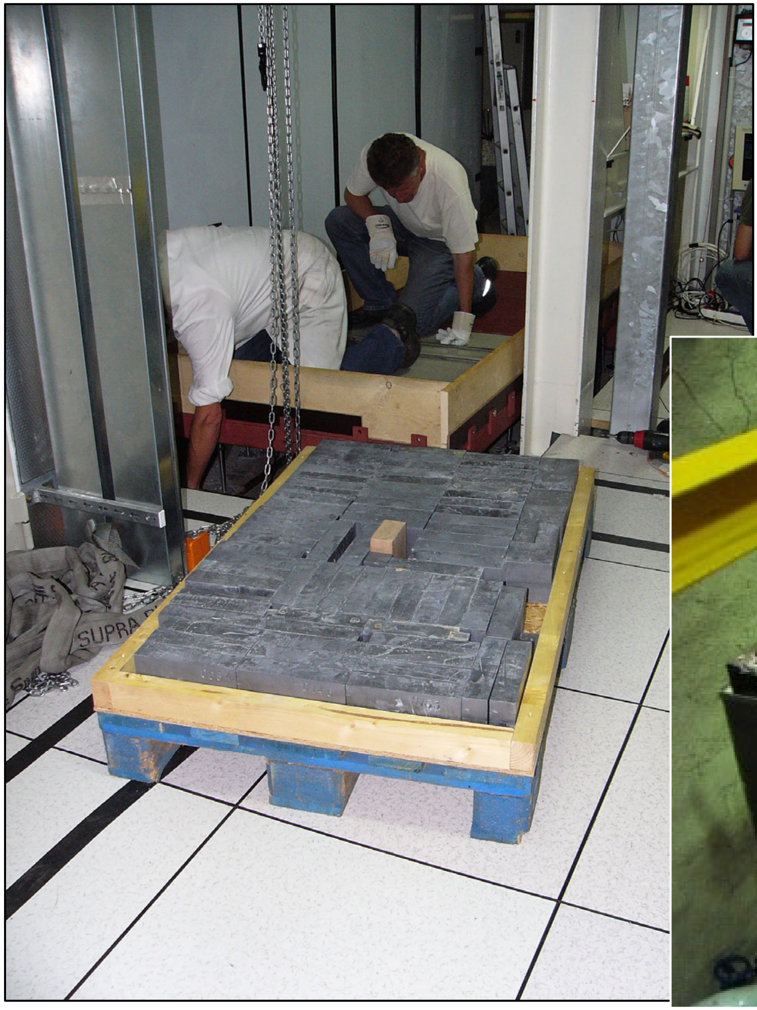
- 2x3 2" PMTs for through going µ´s
- VME based DAQ
- vapour/leak/temp. sensors
- integrated in existing µ-veto DAQ

Folie 9

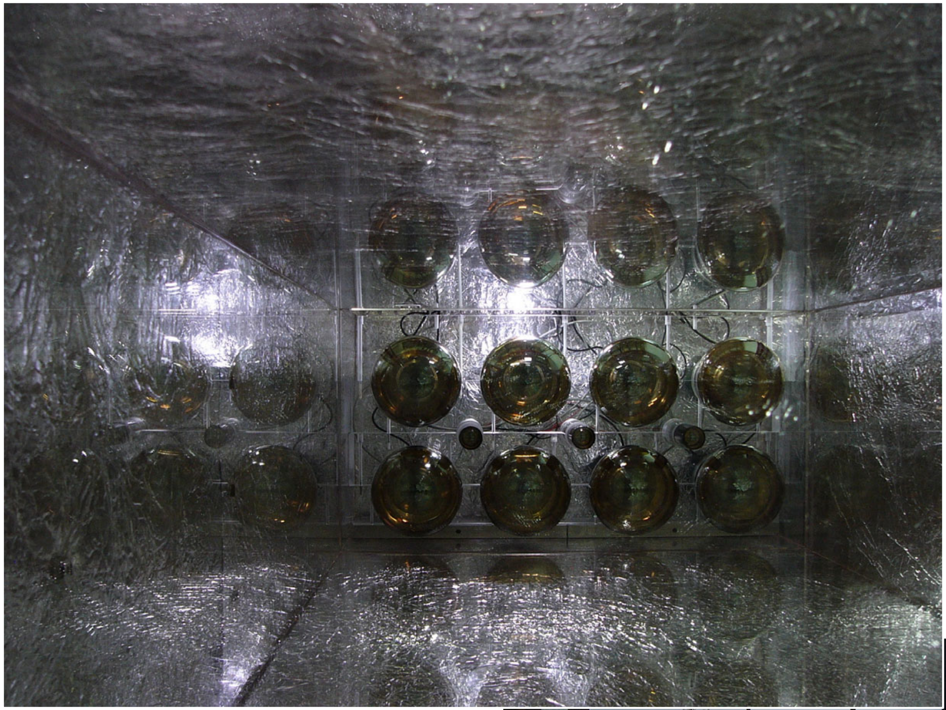
HK6 sfb logo??

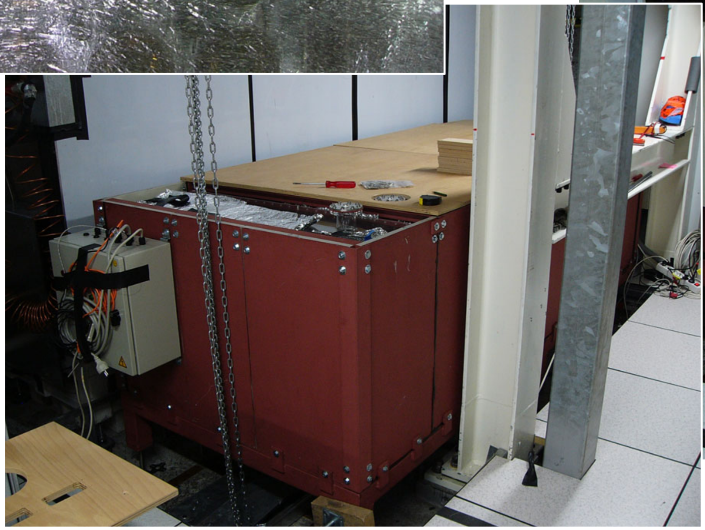
Holger Kluck; 04.03.2009

Picture gallery of installation (Sept 2008)



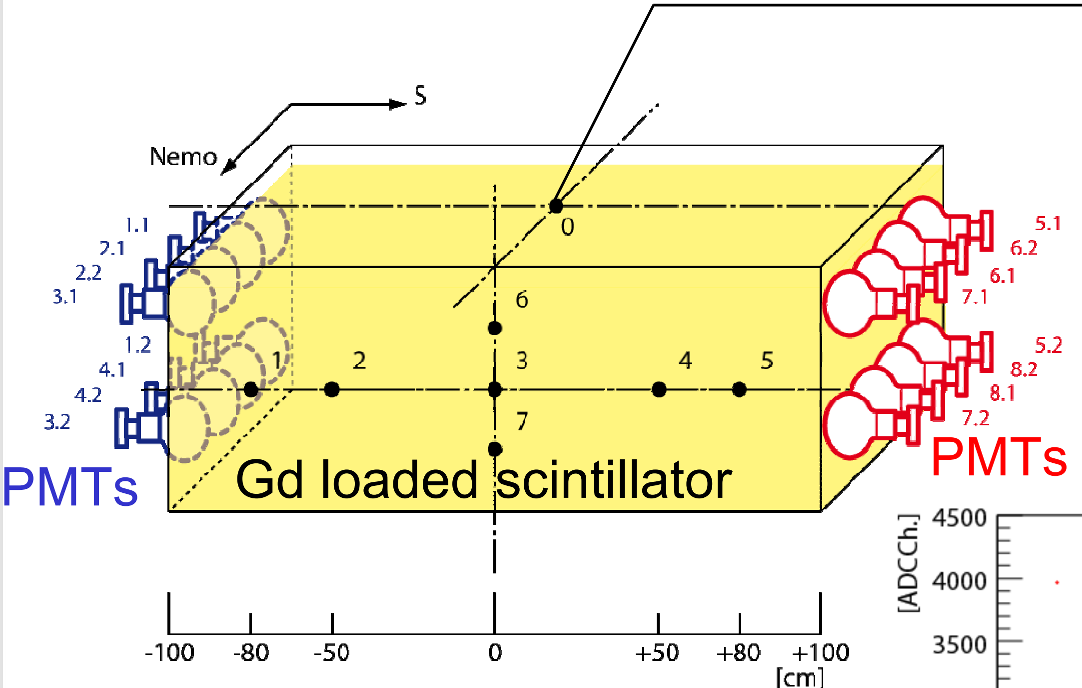
Picture gallery of installation (Sept 2008)

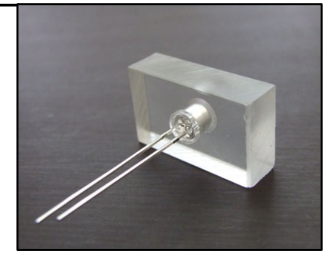




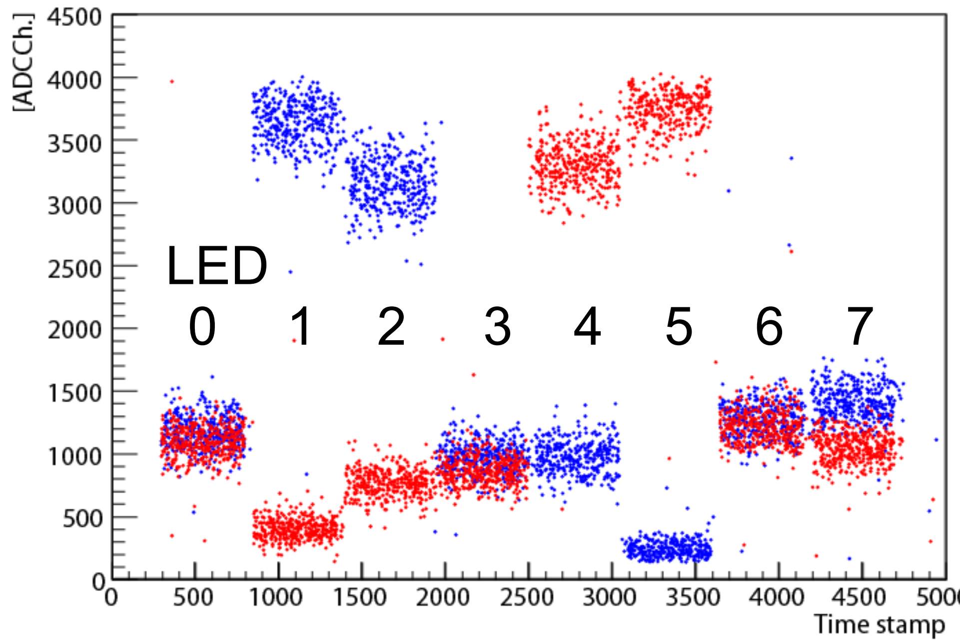
→Data taking since Nov 2008

LED monitoring of scintillator: basics





8 LED's, λ=420 nm
= wavelength of
scintillation light



Using ns light pulser to simulate
scintillation light
→signal source for monitoring

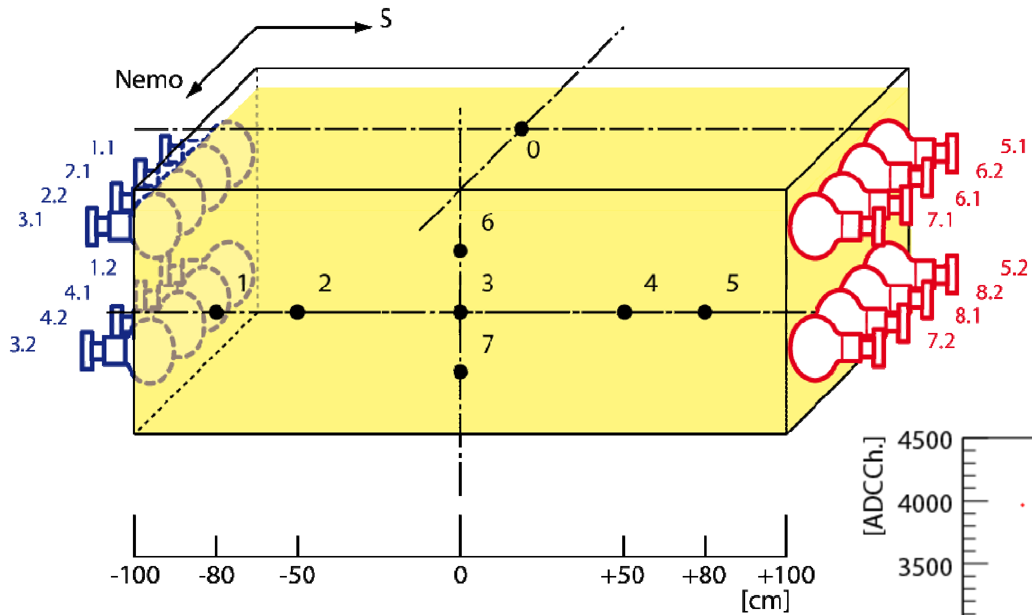
Folie 12

HK7 Reference auf LED design/paper

Holger Kluck; 03.03.2009

HK3

LED monitoring of scintillator: basics

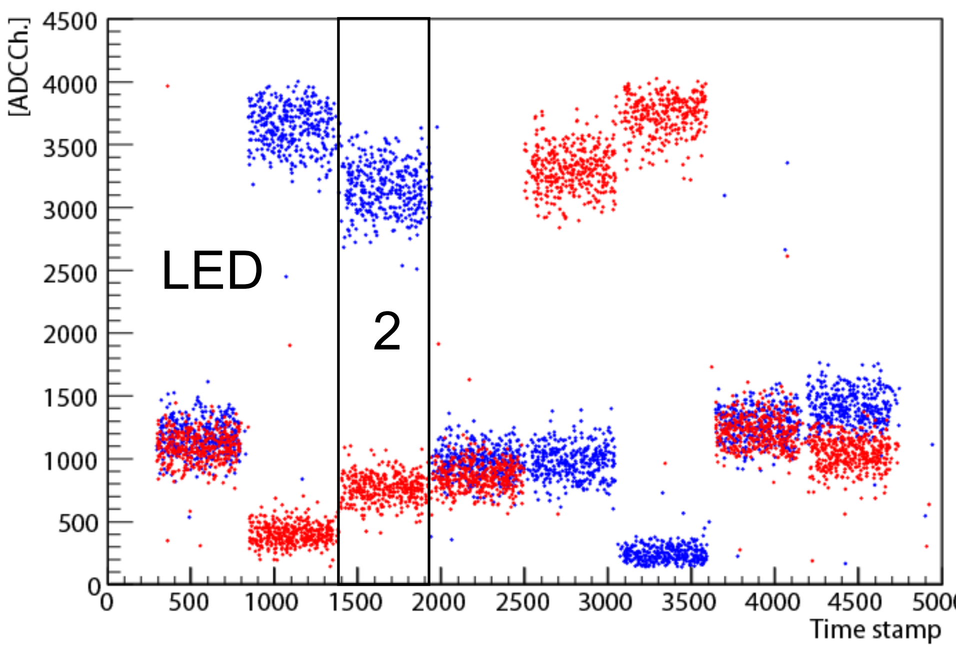


ratio r = near PMT / distant PMT

→ indicator scintillator stability

Using ns light pulser to simulate scintillation light

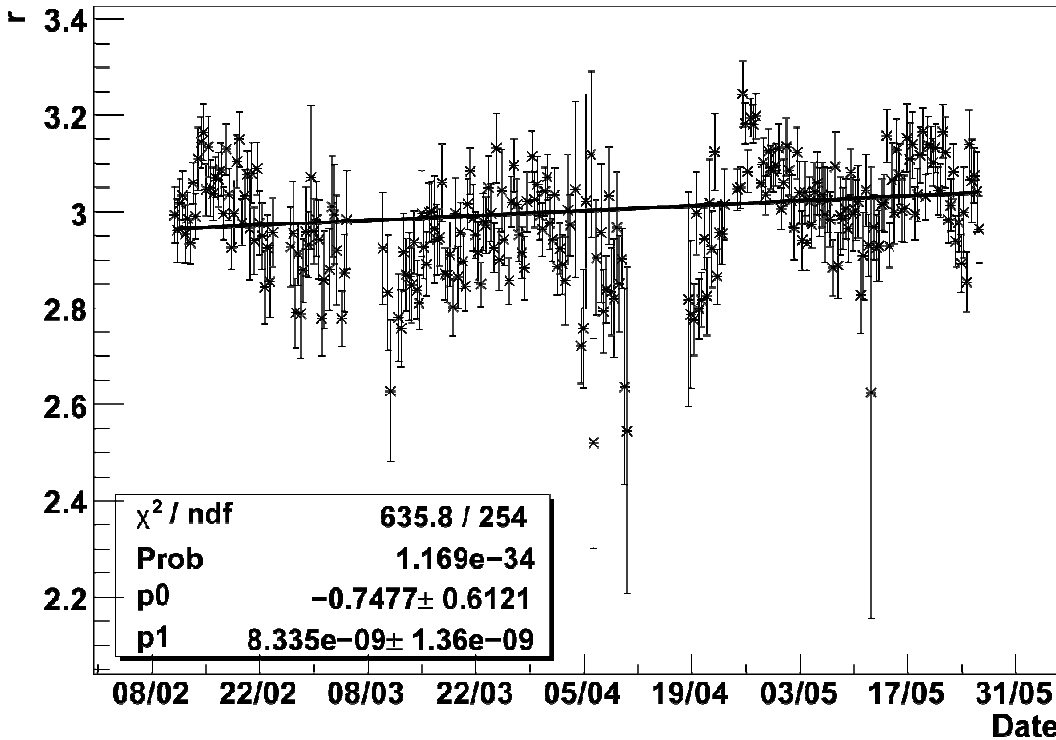
→signal source for monitoring

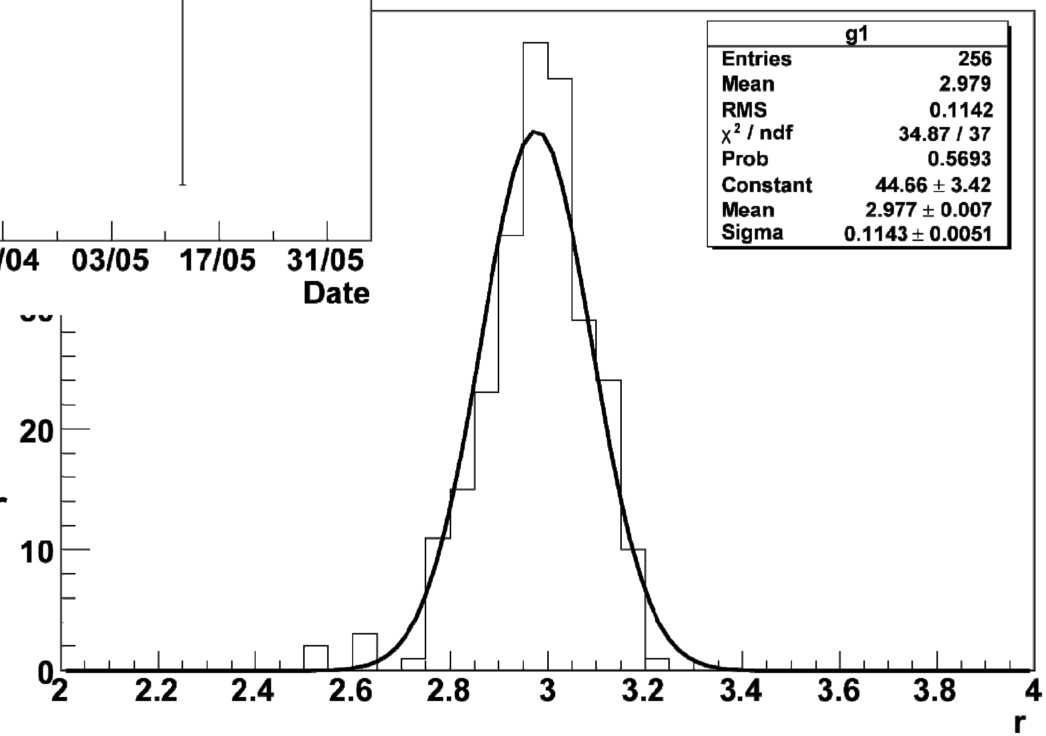


HK3 time evoltion diagramm überarbeiten, Graph grün färben

Holger Kluck; 04.03.2009

Long term behaviour of the transparency





→ shift of +(8.8±1.4)% per year

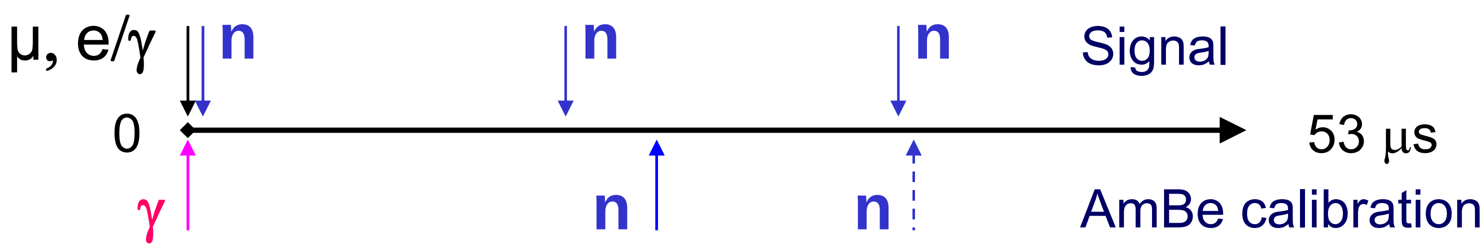
Folie 14

HK9 time evoltion diagramm überarbeiten, Graph grün färben

Holger Kluck; 04.03.2009

Calibration with AmBe source: n+γ

DAQ time window:



^{241}Am

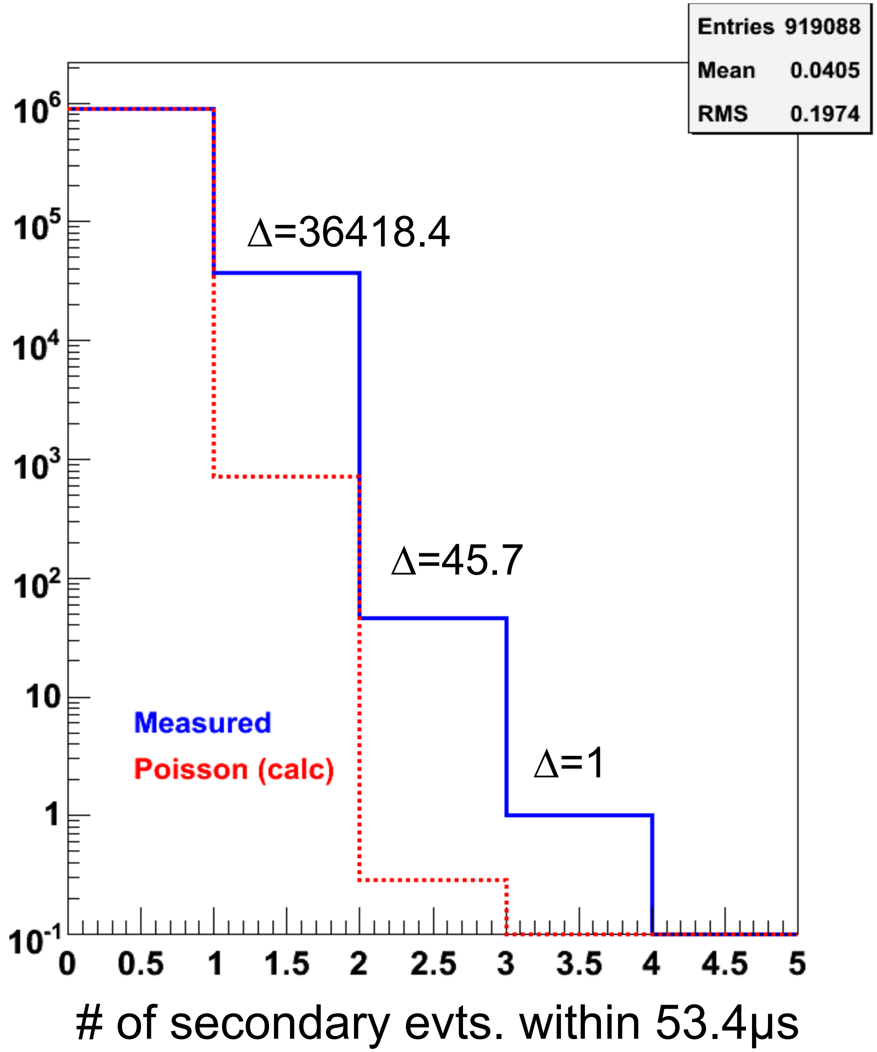
$\rightarrow \alpha + {}^{9}Be \rightarrow {}^{13}C$

$\rightarrow {}^{12}C + n$

$\rightarrow {}^{12*}C + n$ (~60% ?)

$\rightarrow {}^{12}C + \gamma$ (4.4 MeV)

AmBe neutron measurement: secondaries



- Neutron source ~20 n/s,
- T_{DAQ}=53.4 μs
- ~17 hours

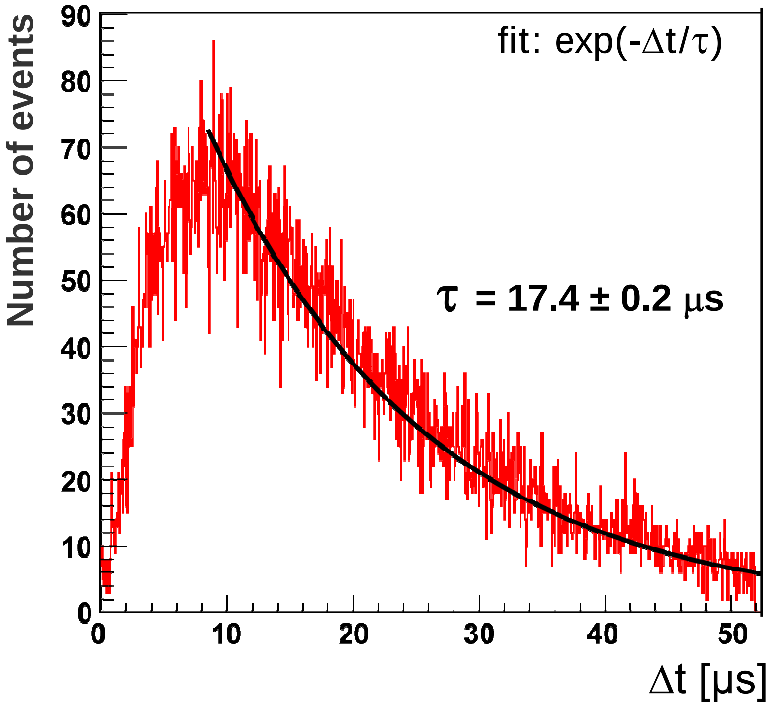
(Δt>1000 ns to avoid PMT after-pulses)

AmBe neutron measurement: Δt

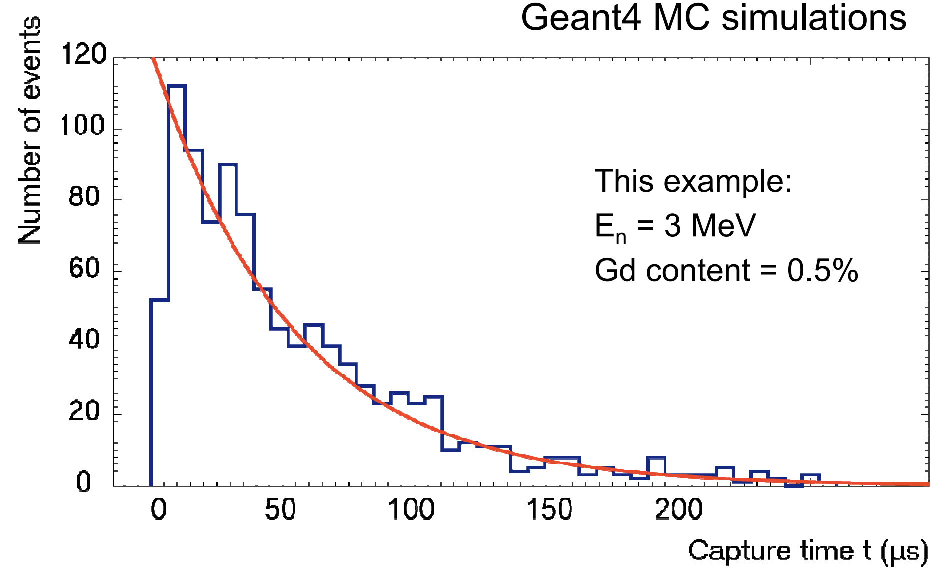
AmBe source: ~20 n/s

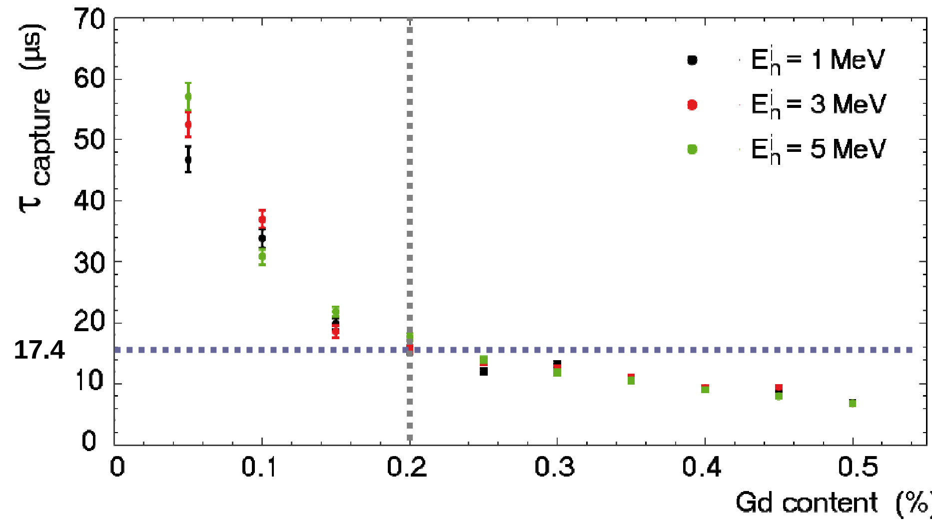
E_n up to ~11 MeV, max. 3 MeV

measurement



Geant4 MC simulations





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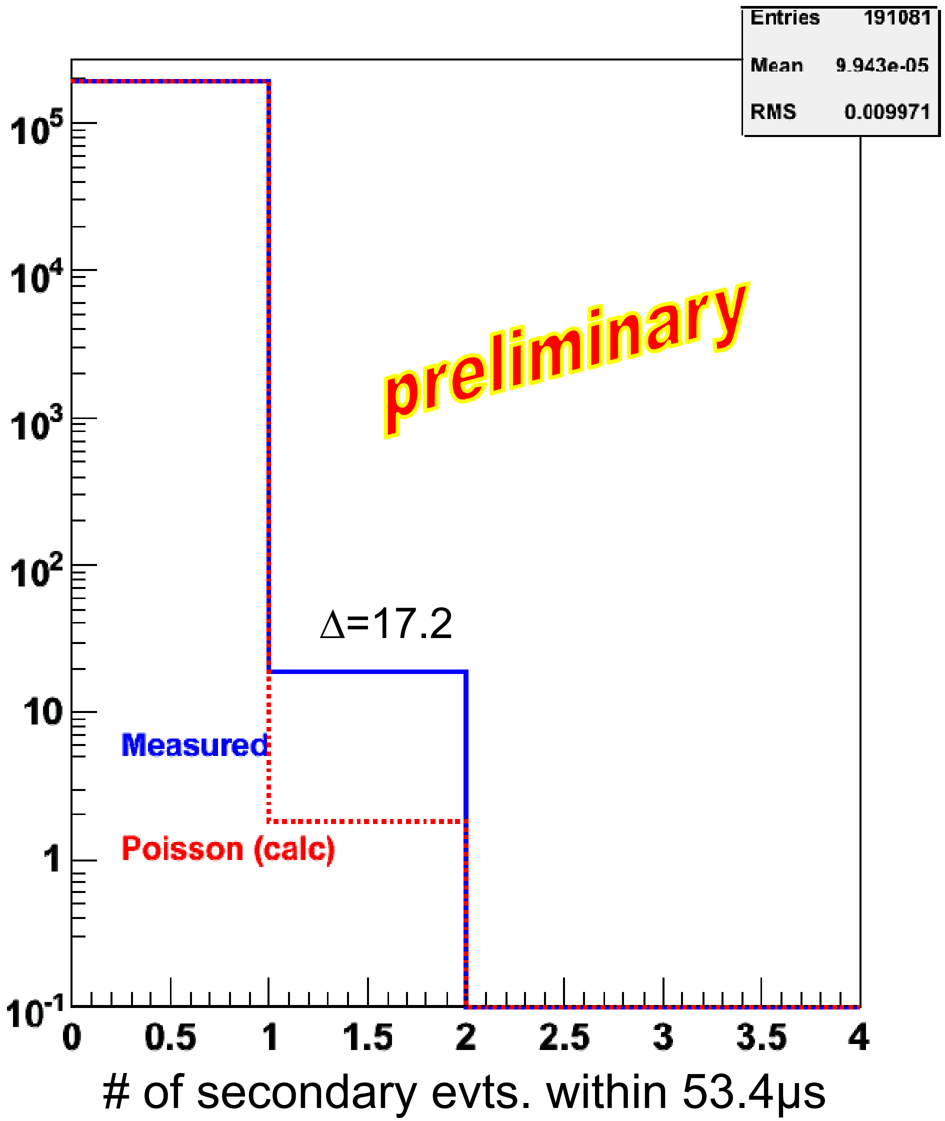
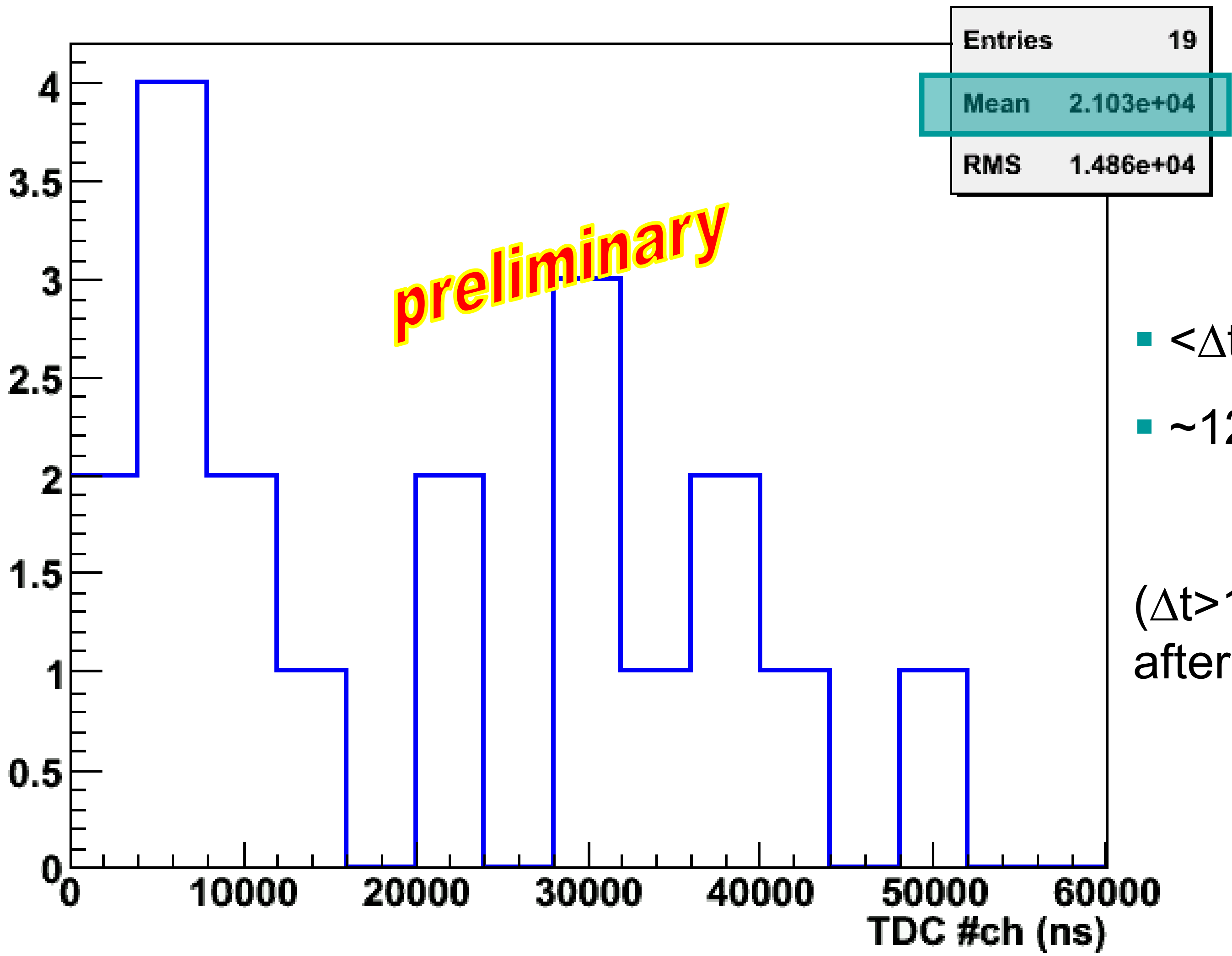
Signal run: secondaries



- No specific selection
- ~12.6 days

(Δt>1000 ns to avoid PMT after-pulses)

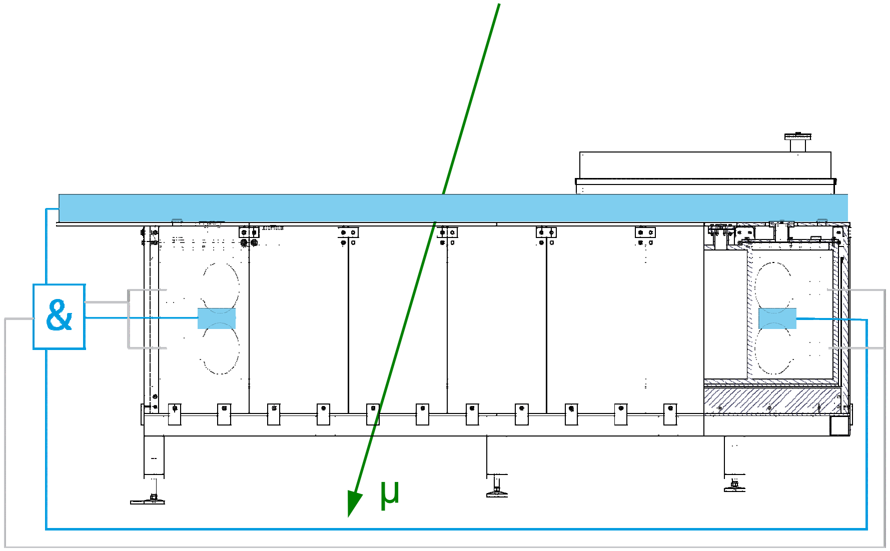
Signal run: Δt_{sec}



- $<\Delta t_{sec}(AmBe)> = 18.3 \mu s$
- ~12.6 days

(Δt>1000 ns to avoid PMT after-pulses)

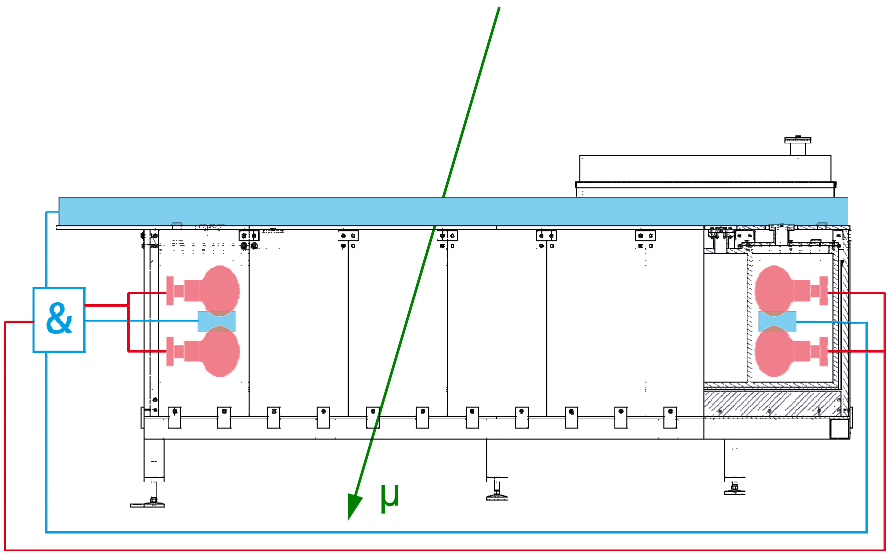
Coincidence with μ-veto system



- Coincidence between μ-Veto and neutron counter
- T_{DAQ}=53.4 μs
- ~51 days

(Δt>200 ns to avoid PMT after-pulses)

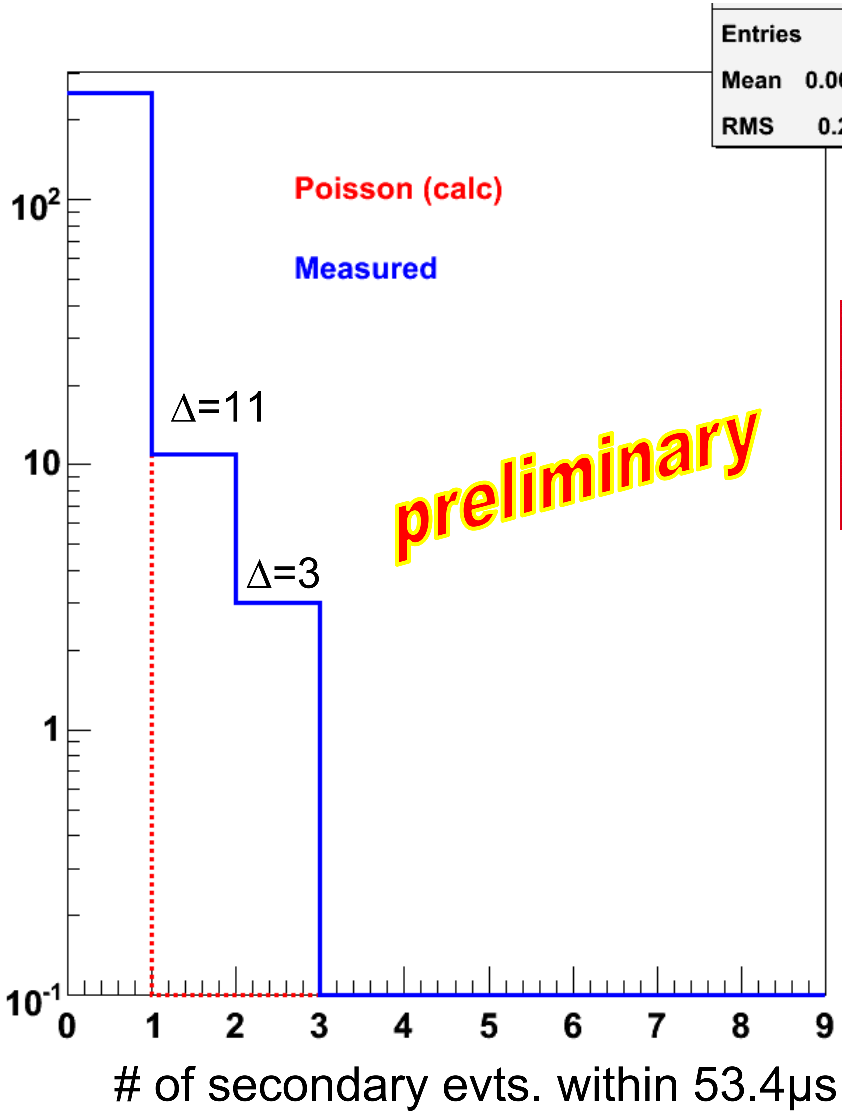
Coincidence with μ-veto system

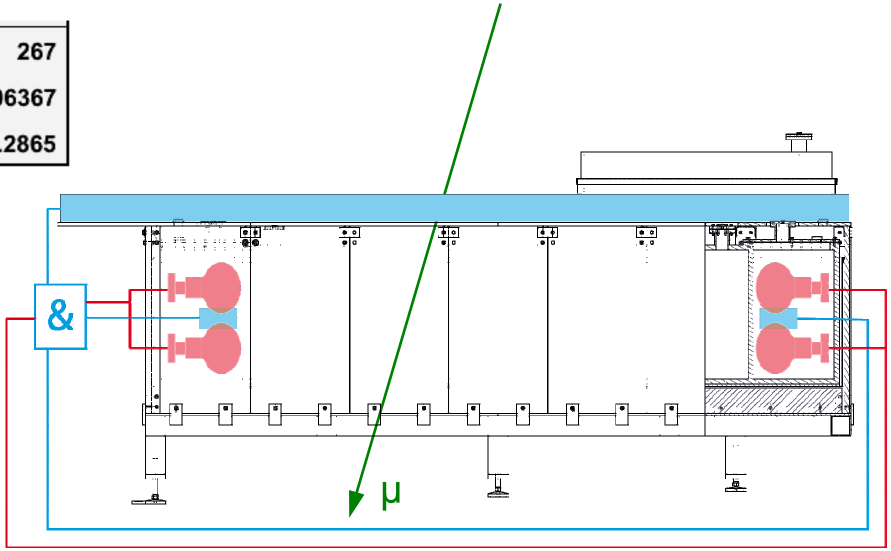


- Coincidence between μ-Veto and neutron counter
- T_{DAQ}=53.4 μs
- ~51 days

(Δt>200 ns to avoid PMT after-pulses)

Coincidence with μ-veto system: sec.

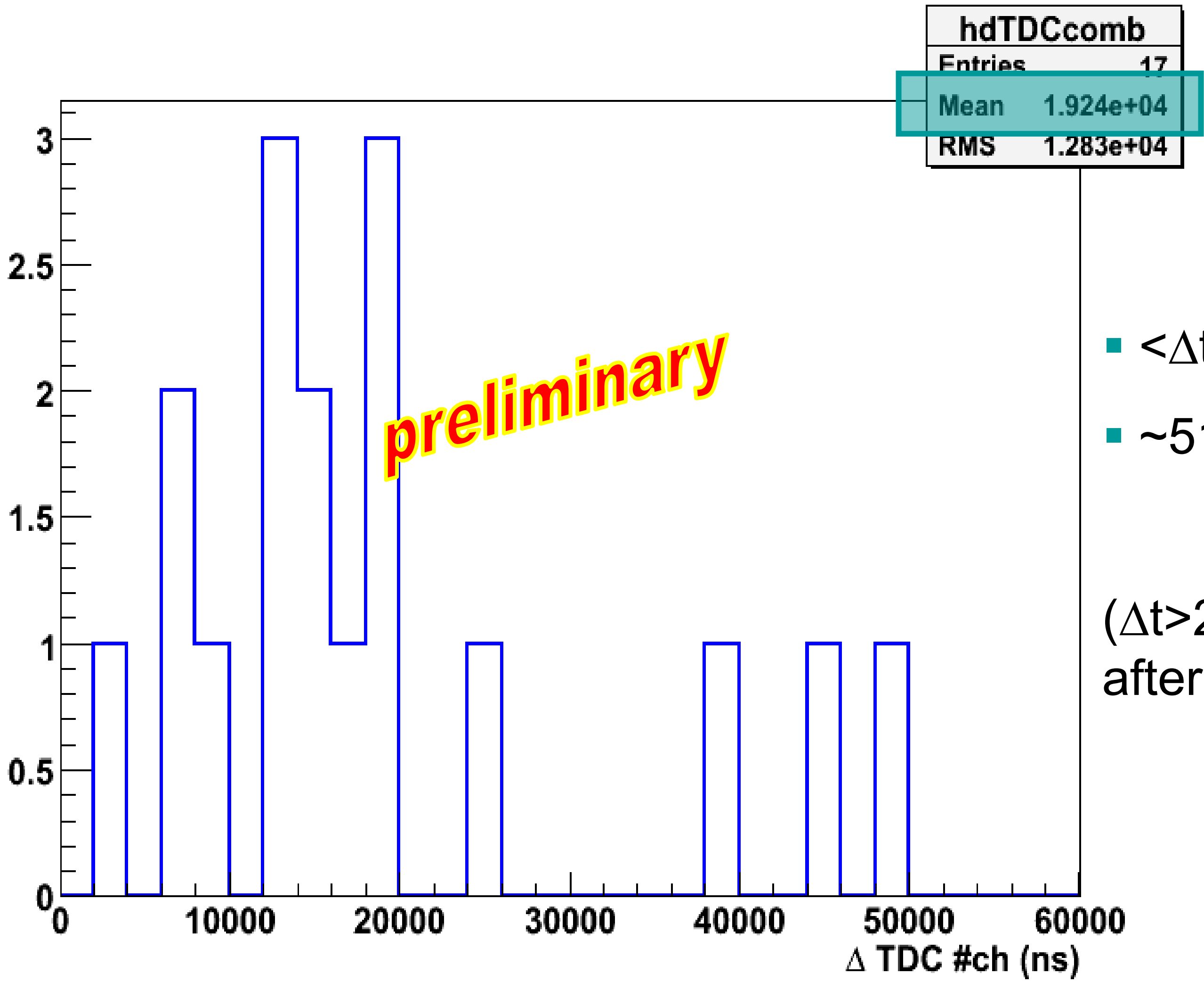




- Coincidence between μ-Veto and neutron counter
- T_{DAQ}=53.4 μs
- ~51 days

(Δt>200 ns to avoid PMT after-pulses)

Coincidence with μ-veto system: Δt_{sec}



- $<\Delta t_{sec}(AmBe)>$ = 18.3μs
- ~51 days

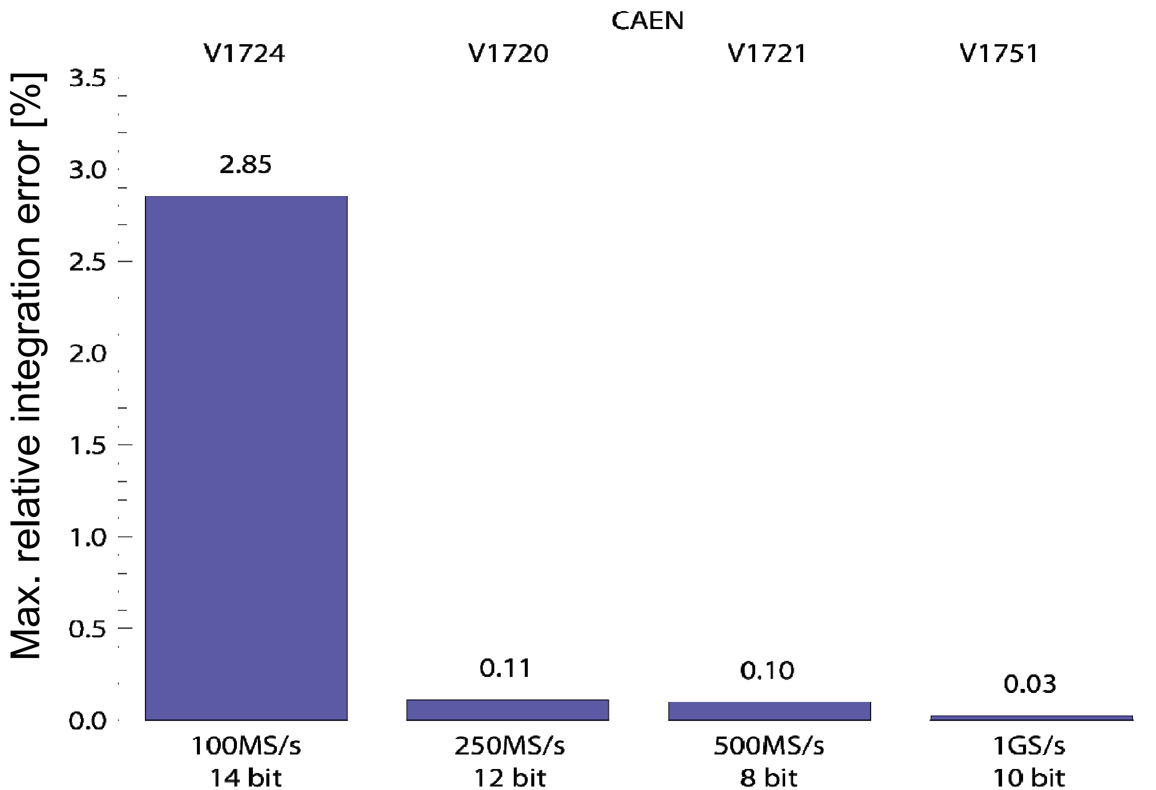
(Δt>200 ns to avoid PMT after-pulses)

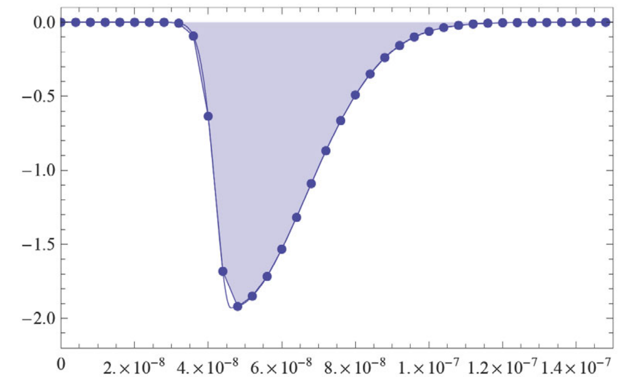
→Candidates for μ induced n's!

Outlook: Upgrade of DAQ electronic

- New timing board (FPGA based) for better synchronization: neutron counter ↔muon veto ↔bolometer
- Minimize DAQ deadtime: QDC → dead time less FADC

Investigate: integration error = f(FADC sampling frequency)



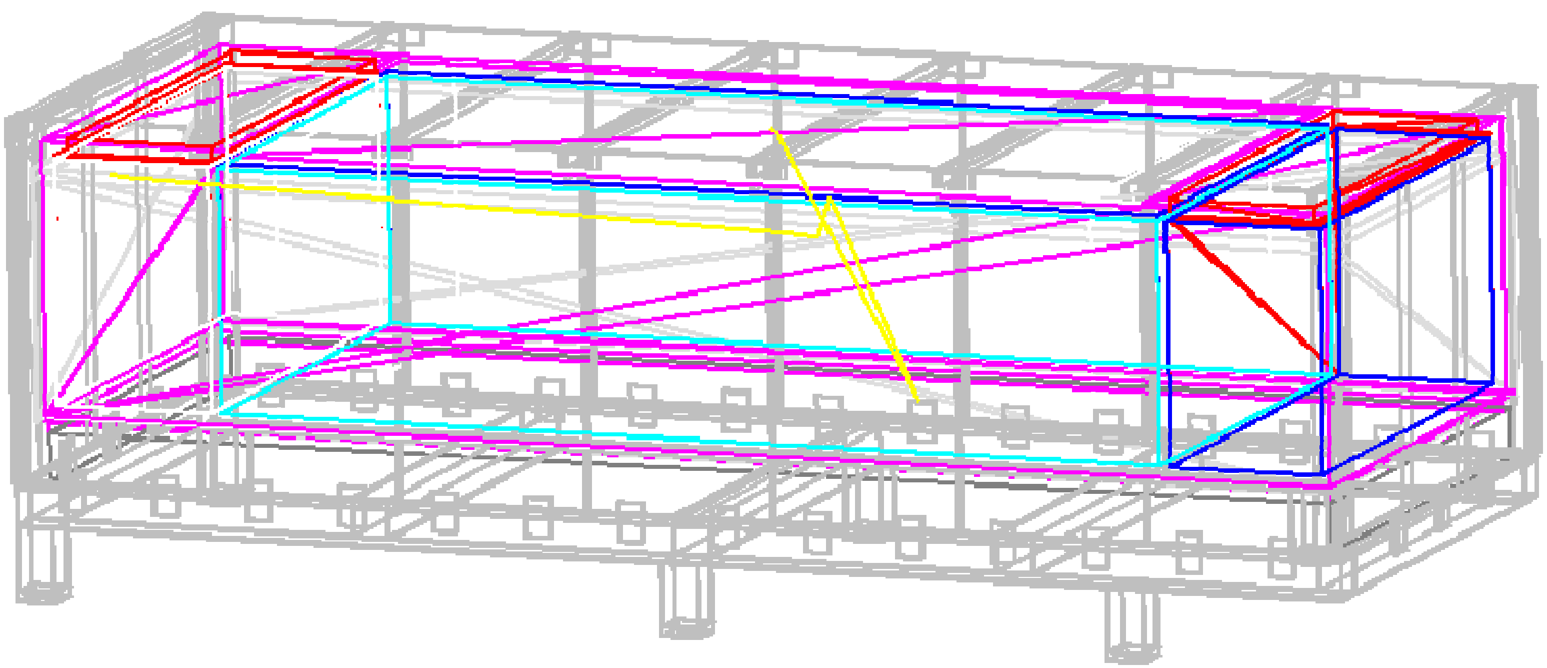


- → CAEN V1720
- 250 MS/s
- relative error ~ 0.1%
- ~700 GByte data/year

Outlook: MC simulations of µ-n detector

Improvement of MC simulations using GEANT4:

- Implementation of the realized neutron counter geometry: ✓
- Next step: physics, light propagation



Summary

Karlsruhe Institute of Technology

➔First candidates for μ-induced n's seen by the EDELWEISS μ-veto in coincidence with the neutron counter

- Neutron counter is installed and take data since Nov 2008
- Continuously monitoring of scintillator stability
  → Stability as expected
- AmBe measurements
  → First neutrons are detected
- Coincidence measurements μ-veto / n counter:
  → First candidates for μ induced n
- Ongoing data taking and analysis
- Upgrade of DAQ electronics
- Improvement of MC simulations with Geant4

SFB-TR27

This work is in part supported by the German Research Foundation (DFG) through the transregional Collaborative Research Center SFB-TR27 as well as by the EU contract RII3-CT-2004-506222

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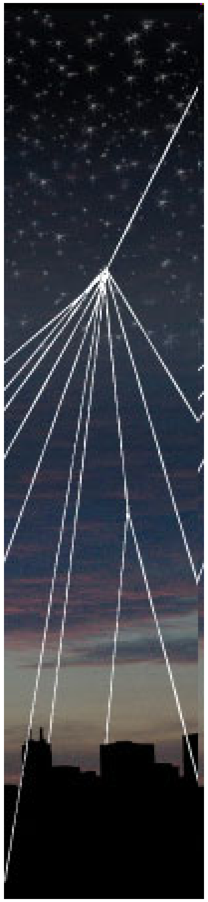
Muons flux: sea level and underground lab

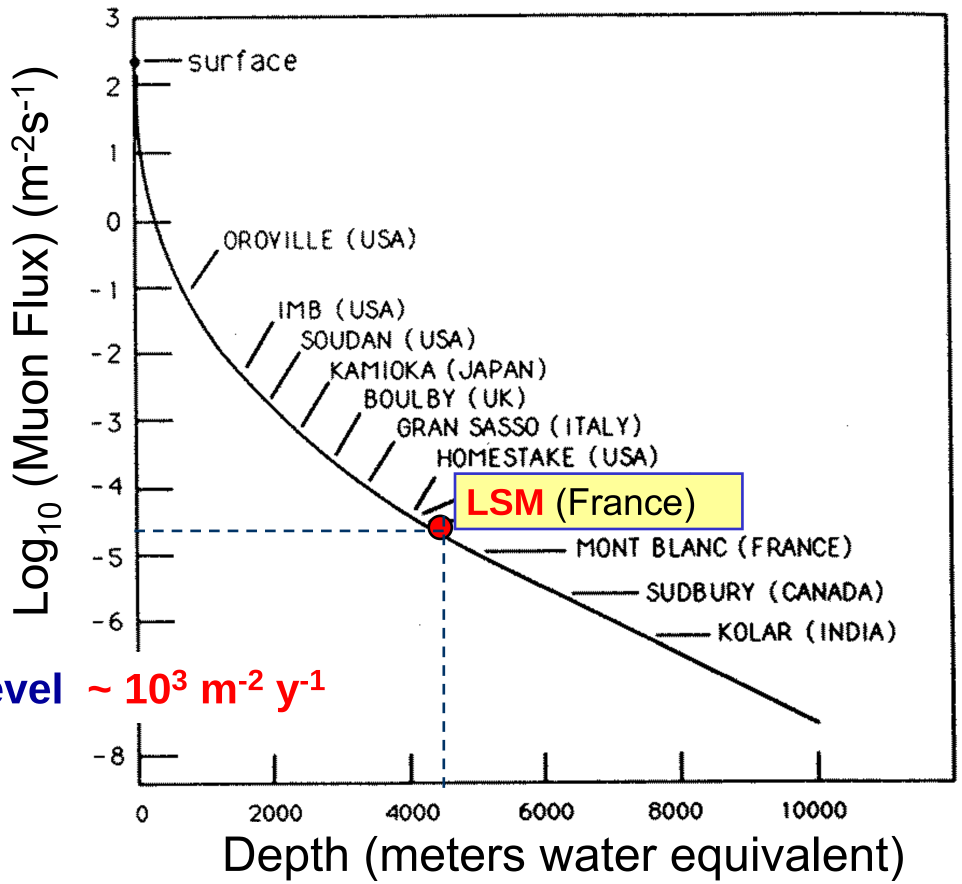


Mainly from:

$$\pi^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}(\overline{\nu}_{\mu})$$

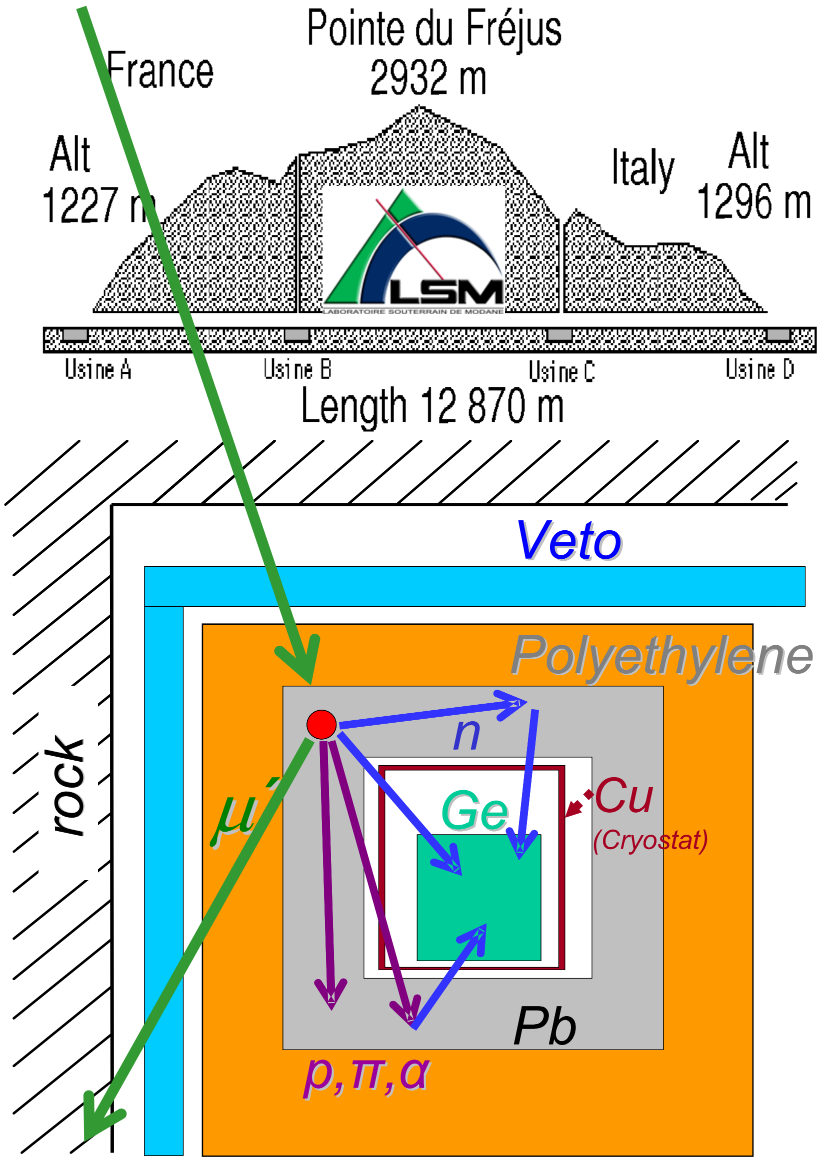
$$K^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu}(\overline{\nu}_{\mu})$$

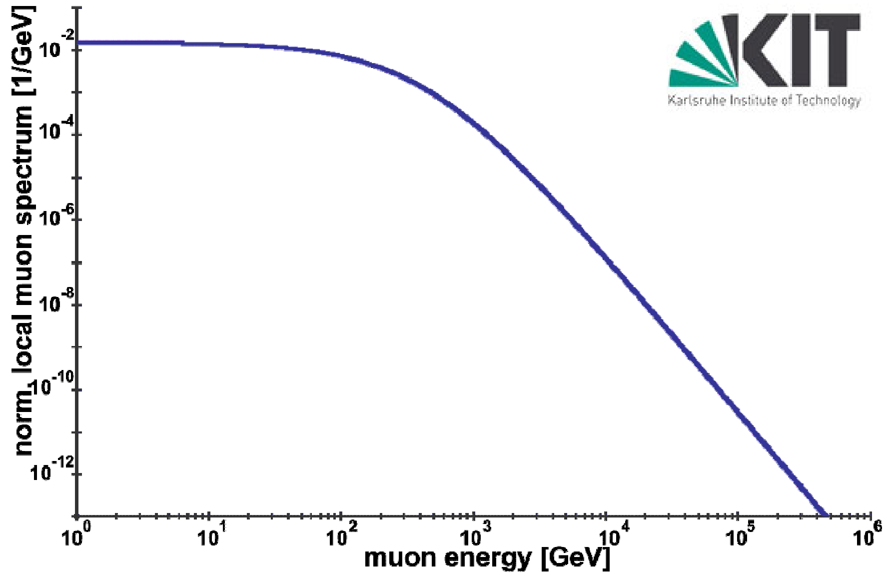
Sea level **3 10^{9} m^{-2} y^{-1}**

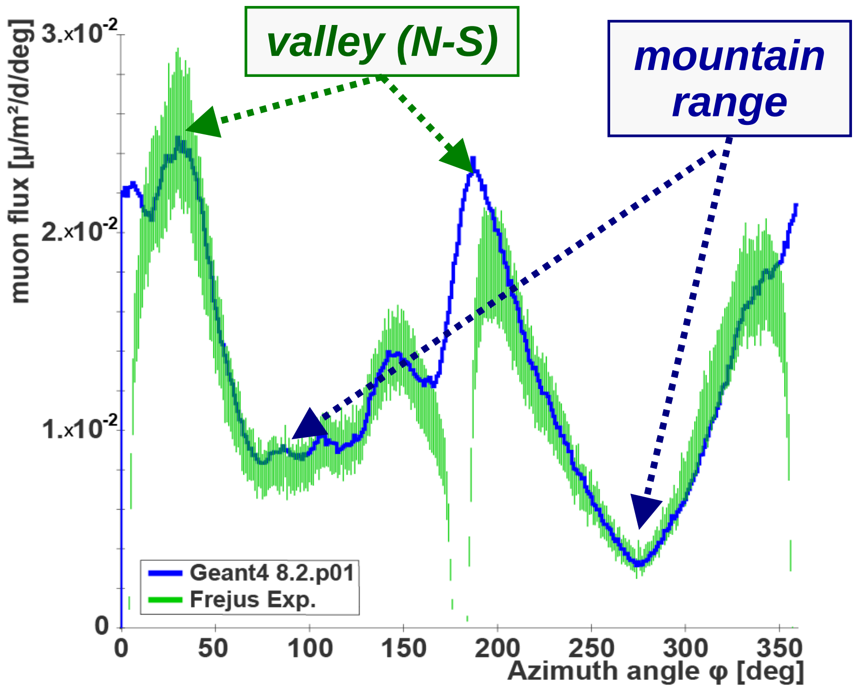


LSM level **~ 10^{3} m^{-2} y^{-1}**

Simulation of µ´s at LSM

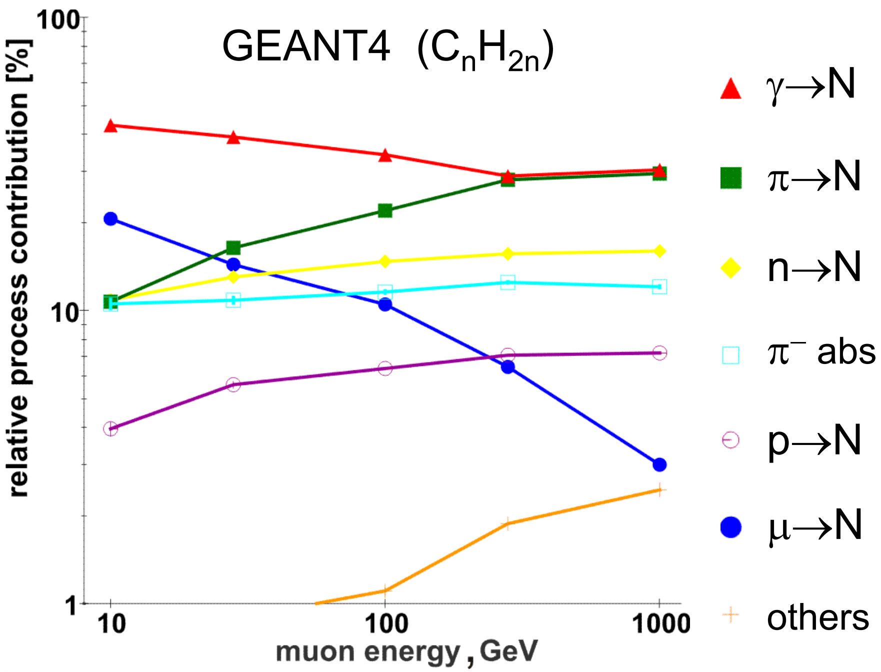


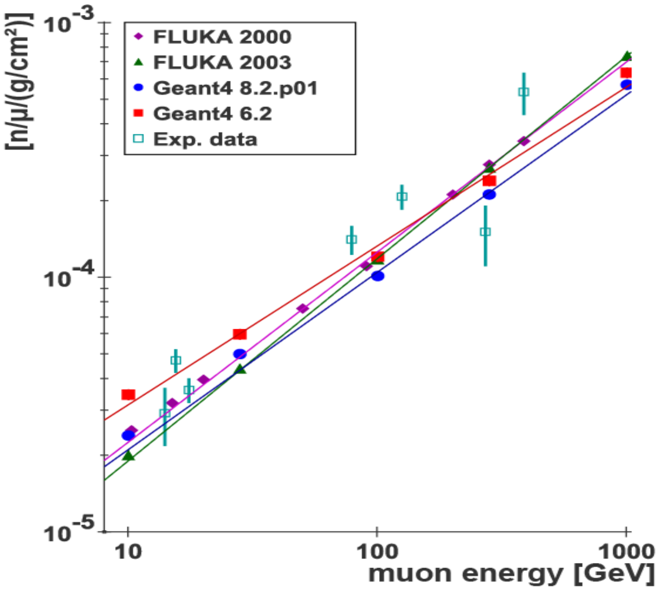


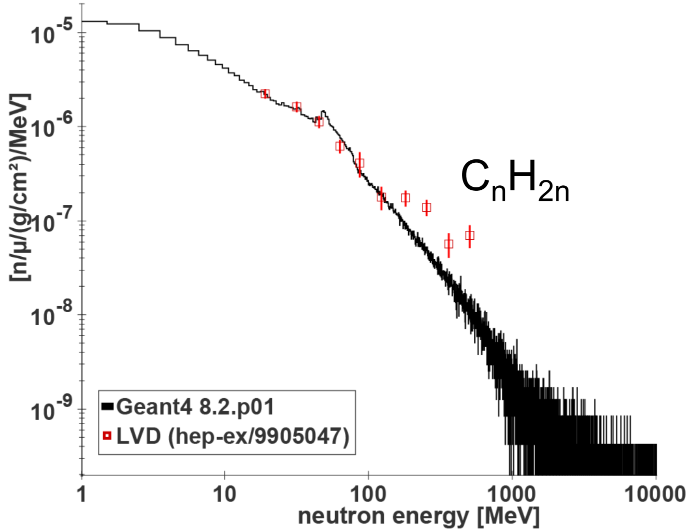


Simulation of μ-induced events

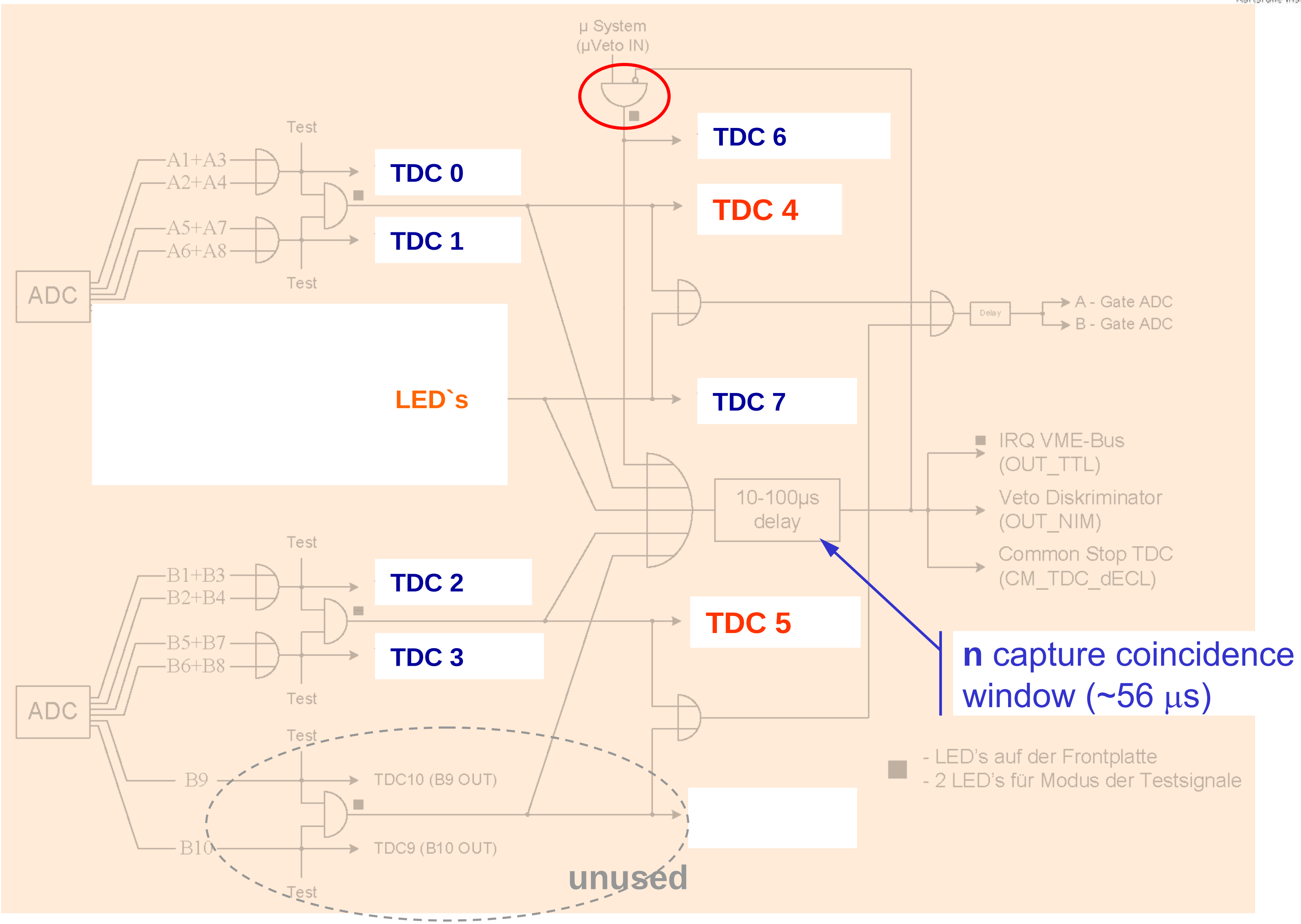
- DM: **n** mimic WIMP recoils (~ few keV);
- 0νββ:
  n (>MeV) => γ rays (inelast. scatt);
  n (therm.) => γ rays (capture);



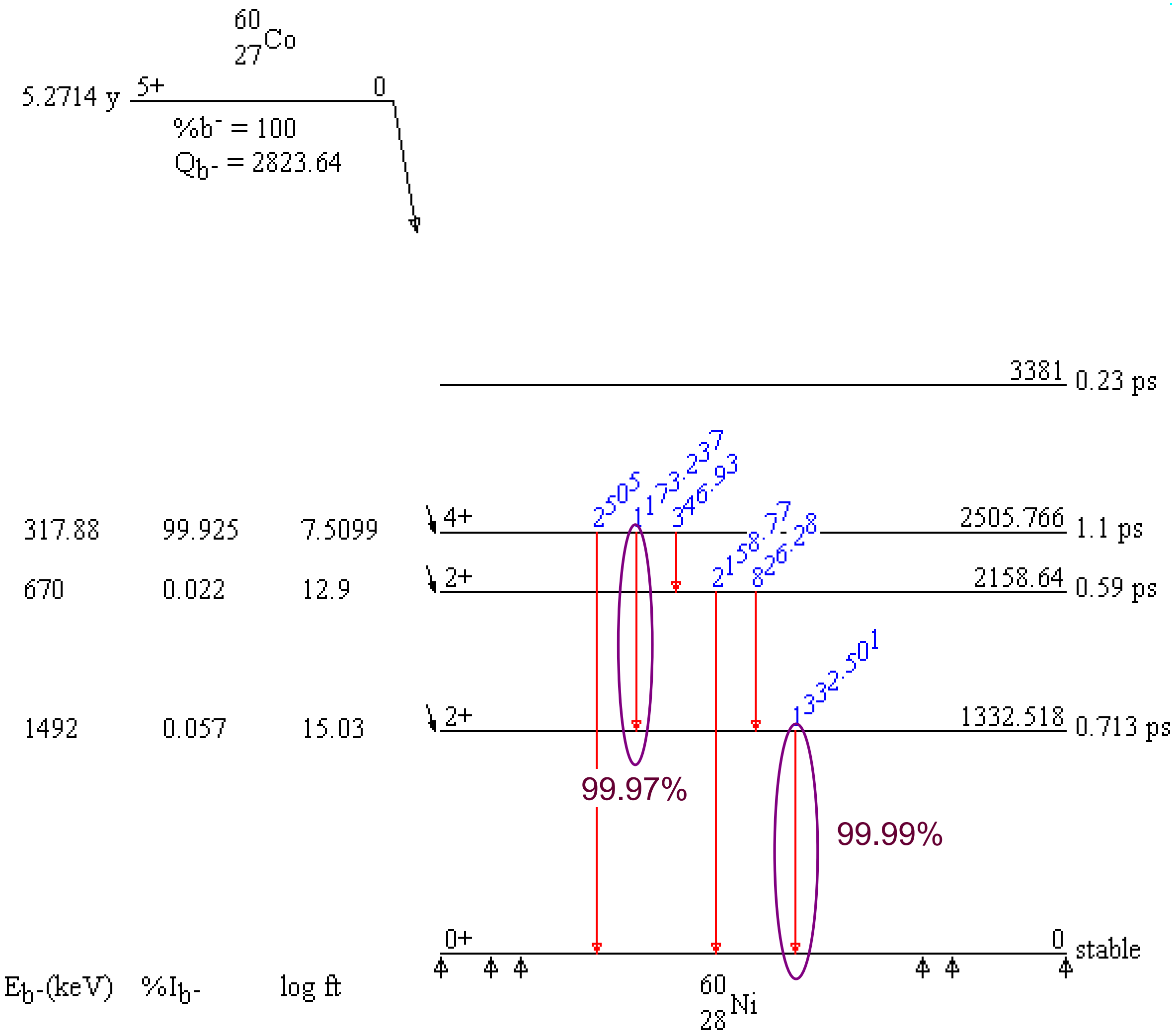




DAQ / coinidence scheme



Co^{60} decay scheme

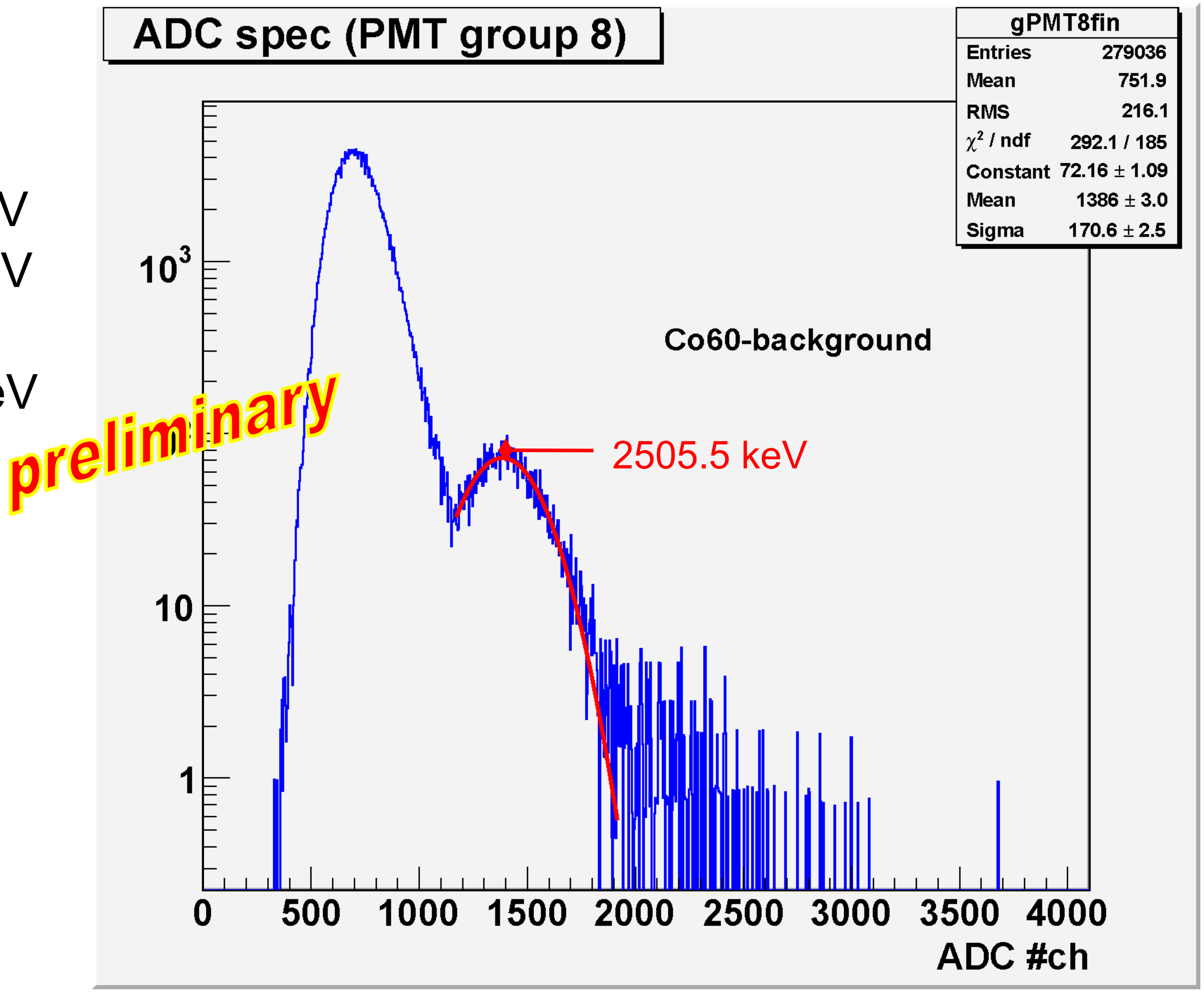


Co60 data: energy calibration

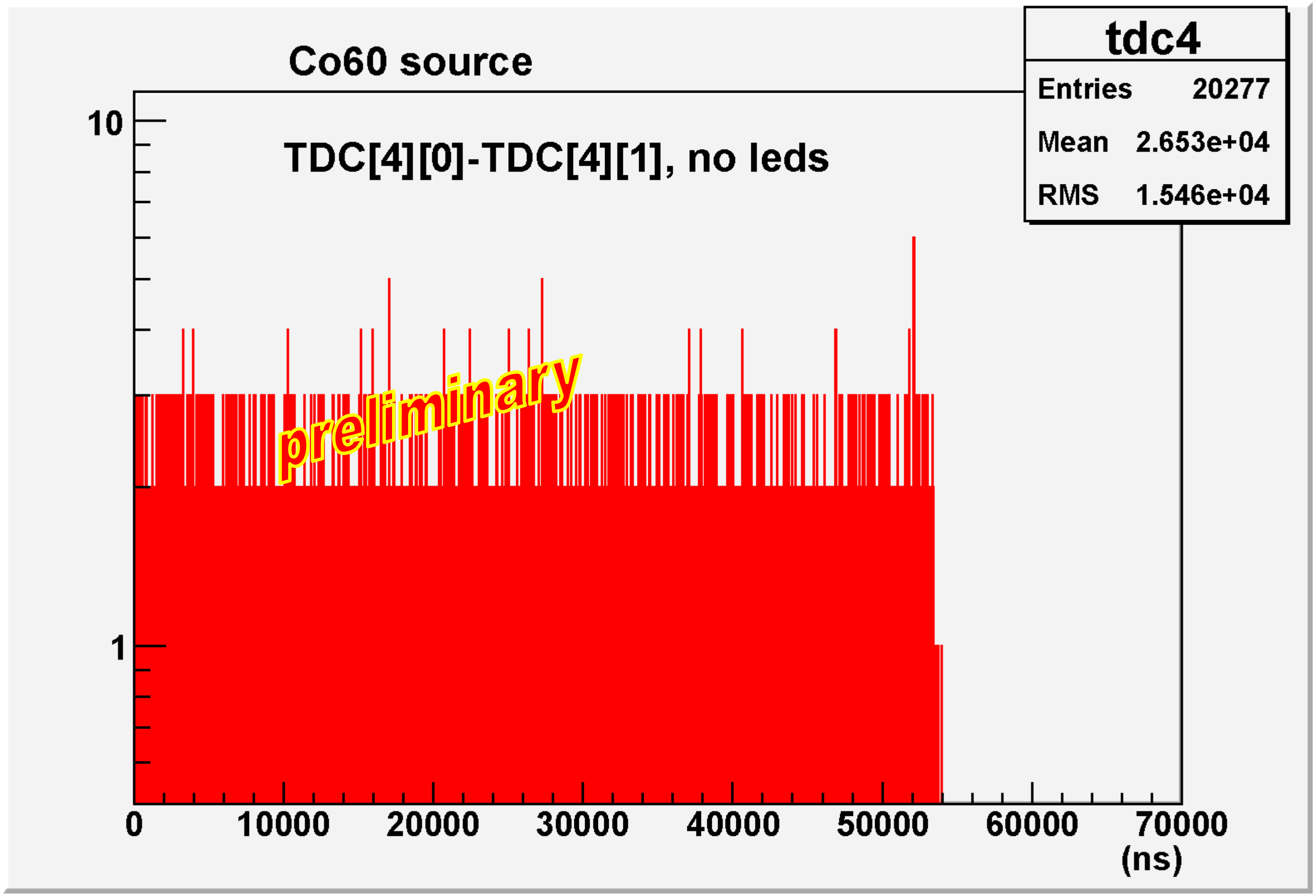
^{60}**Co** source:

γ_1 =1173 keV
γ_2 =1332.5 keV

$(\gamma_1+\gamma_2)$=2505.5 keV



Co60 data: Δtdc for 2 hits within the events



Timing of background events