

IDM 2010

8th International Workshop on
Identification of Dark Matter
University of Montpellier 2
26-30 July 2010
www.lpta.univ-montp2.fr/idm2010



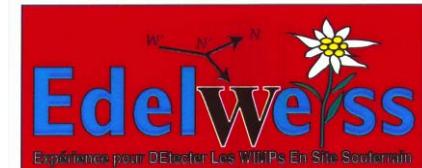
Neutron background studies for direct dark matter searches in LSM

Institute for Nuclear Physics, Karlsruhe Institute of Technology

Valentin Kozlov for **EDELWEISS**

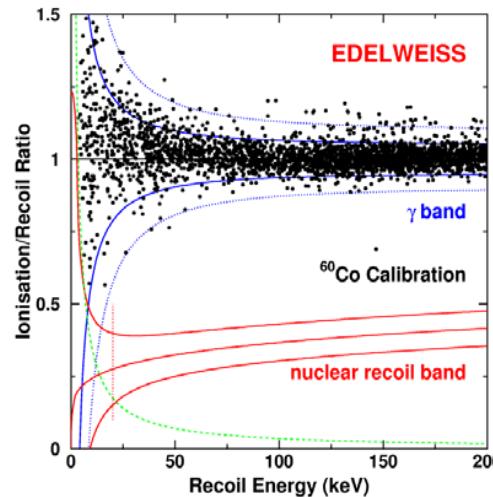
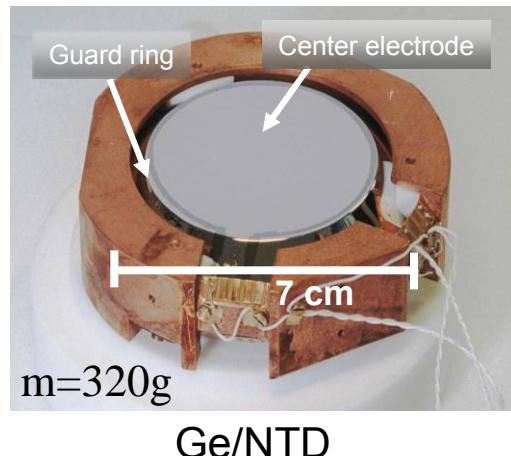
26 – 30 July, 2010, Montpellier, France

- Neutron background in DM search with Edelweiss-2/EURECA → E.Armengaud (26.07)
- Measurement of ambient neutron H. Kraus (30.07)
- Strong AmBe calibration ⇔ simulations V.Kudryavtsev (30.07)
- Studies of muon-induced neutron background

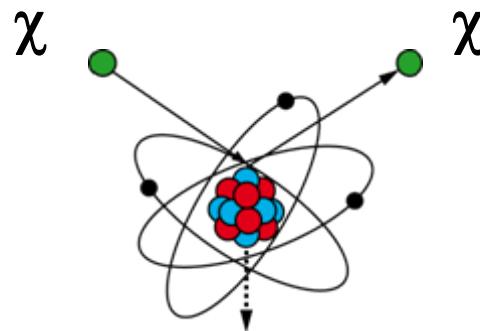


n's as background for direct DM search

- ❖ EDW: bolometers of pure natural Ge @LSM (4850 mwe):



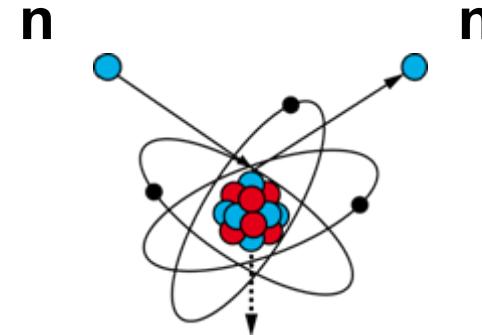
- **Simultaneous measurement**
 - Heat @ 17 mK with Ge/NTD thermometer
 - Ionization @ few V/cm with Al electrodes
- **Evt by evt identification** of the recoil by ratio $Q = E_{\text{ionization}} / E_{\text{recoil}}$
 - $Q=1$ for electron recoil
 - $Q \approx 0.3$ for nuclear recoil



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

$$\left. \begin{array}{l} v(\chi) \sim 300 \text{ km/s} \\ m(\chi) \sim 70 \text{ GeV} \end{array} \right\} E_{\text{rec, max}} \sim 35 \text{ keV}$$

rate < 0.01 evt / kg.d

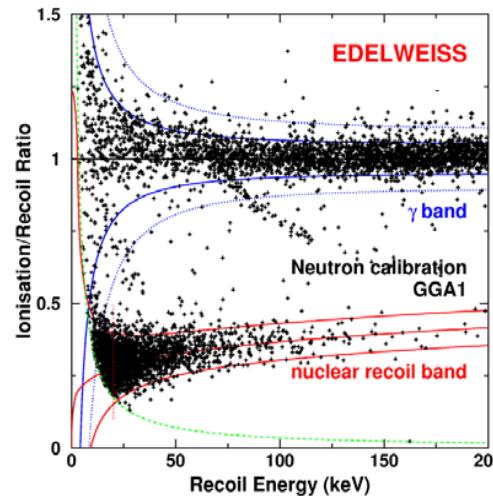
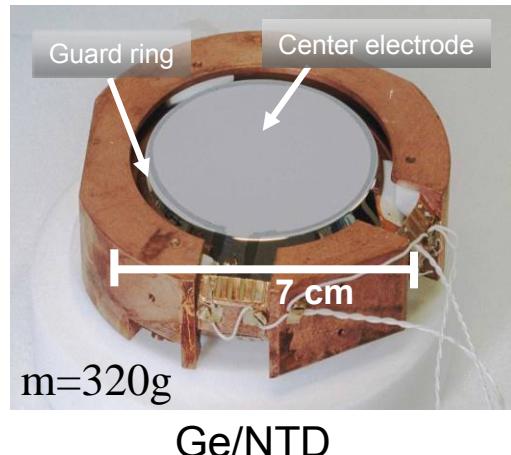


$$\rightarrow E(n) \sim 0.6 \text{ MeV}$$

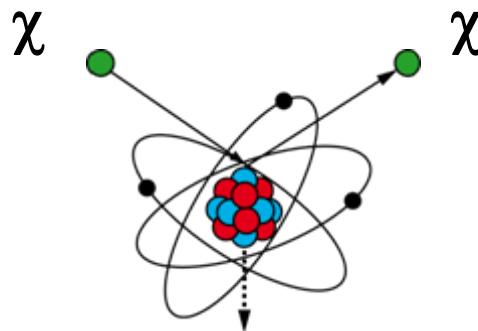
rate = ??

n's as background for direct DM search

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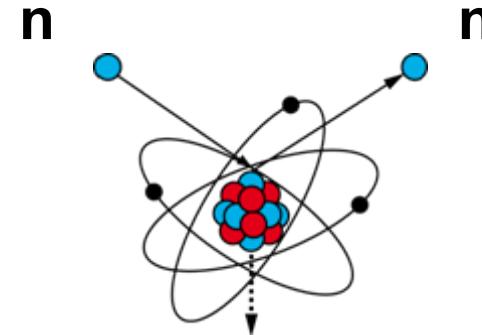
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elastic scattering
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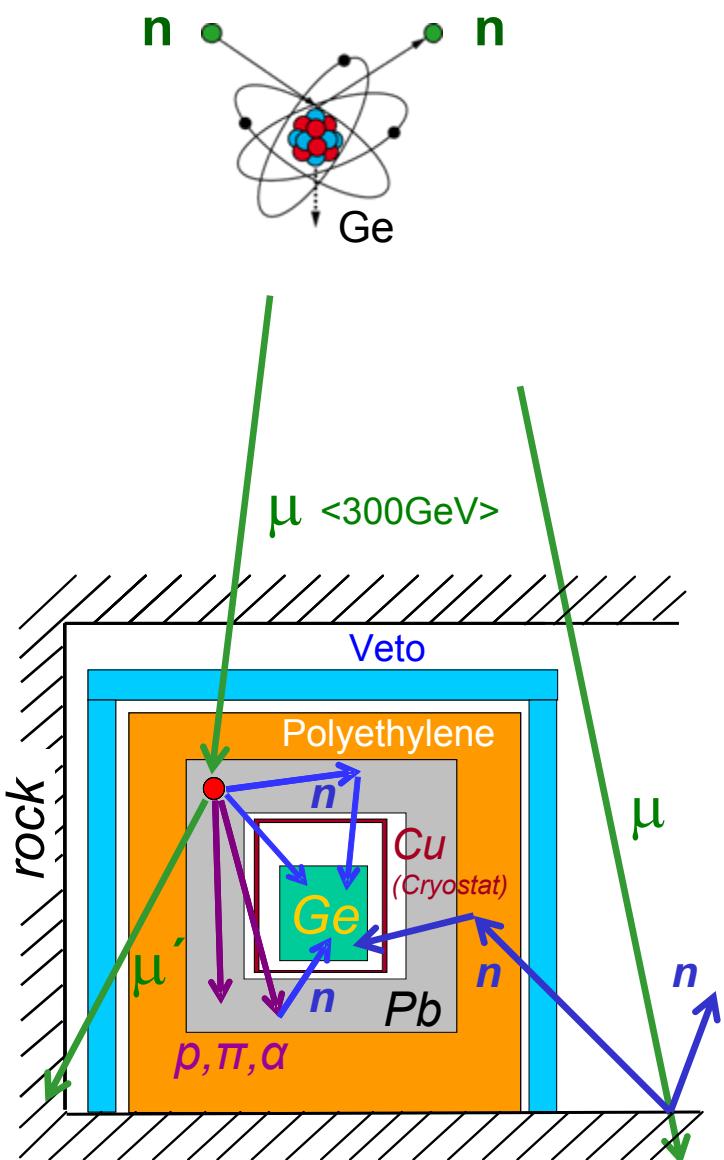
rate < 0.01 evt / kg.d



$$\rightarrow E(n) \sim 0.6 \text{ MeV}$$

rate = ??

Sources of neutrons



- ❖ **Fission & (α, n) reactions (<10 MeV)**
 - in rock/concrete
 - fission in detector shield(!)

→ Passive shielding:
20cm Pb + 50cm PE shielding (EDW-II)
 ^3He detector inside the shields!
- ❖ **Muon induced neutrons (<1 GeV)** produced :
 - In the detector material
→ active μ -vetoing + Simulations;
 - In the surrounding rock (high-E n!)
→ Simulations;
but ... reliable simulations
=> **Need explicit μ -n measurement!**
1m³ Gd-loaded neutron counter

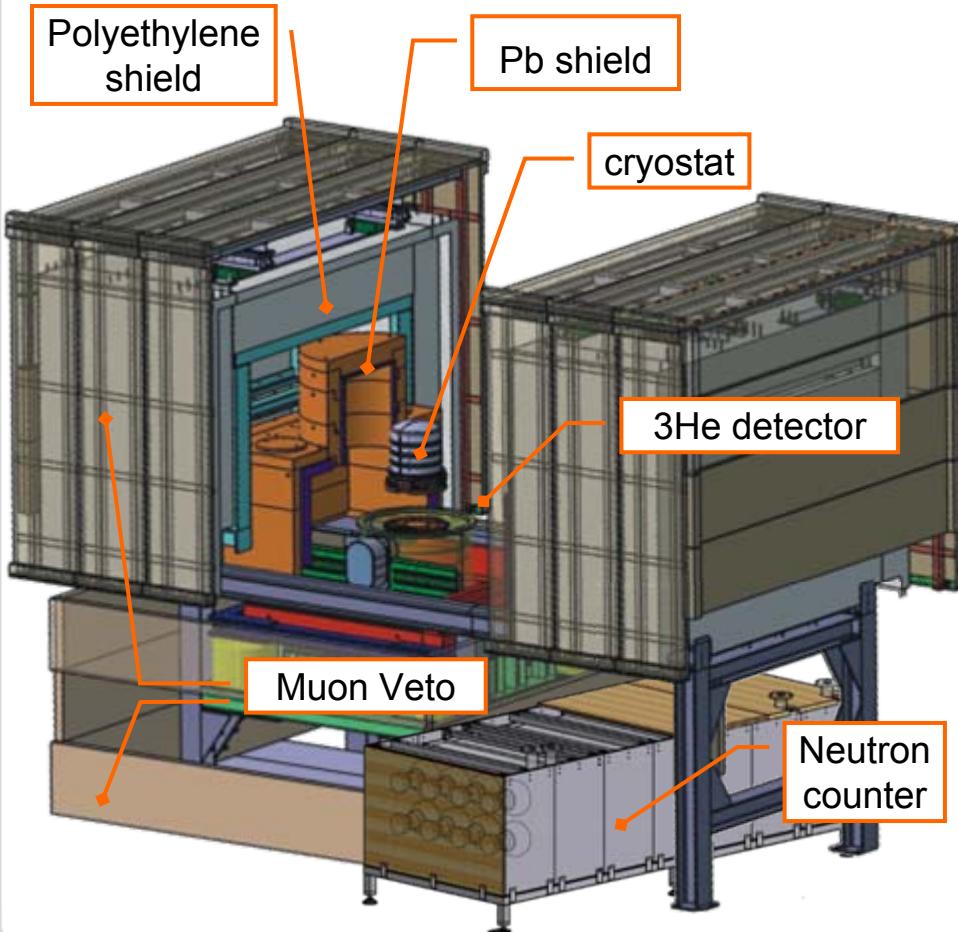
EDW-2 (3) experimental set-up

→ E.Armengaud (26.07)



Shielding: ~ 4850 mwe

μ -flux: ~ 5 μ / m² / day



- **Goal** $\sigma_{\chi-n} = 5 \cdot 10^{-9}$ pb (~ 10^{-3} evt/kg.d)
- **Cryogenic installation (18 mK) :**
 - Can host up to 40 kg of bolometer
- **Shieldings :**
 - Clean room + deradonized air
 - Active muon veto (>98% coverage)
 - PE shield 50 cm
 - Lead shield 20 cm

⇒ γ background reduced by ~3 wrt EDW-1
- **Background studies :**
 - Radon detector down to few mBq/m³
 - thermal neutron monitoring (He^3 det.)
 - Muon-veto – bolometer coincidences
 - Strong AmBe source calibrations
 - Study of muon induced neutrons (liquid scintillator 1 m³ neutron counter)

Edelweiss-2: current background budget

■ <i>Gamma:</i>	^{133}Ba calib rejection x observed bulk γ	<1.0
■ <i>Beta:</i>	β source rejection x observed surface evts	<0.2
■ <i>Neutrons from μ's:</i>	μ veto efficiency x observed muons	<0.25
■ <i>Neutrons from Pb:</i>	measured U limits x Monte Carlo simu	<0.1
■ <i>Neutrons from rock:</i>	measured neutron flux x Monte Carlo simu MC tuned with outside strong AmBe source	<0.1
		} <0.45

SUM (background) for the whole WIMP run (322 kg.d): < 1.6 (90% CL)



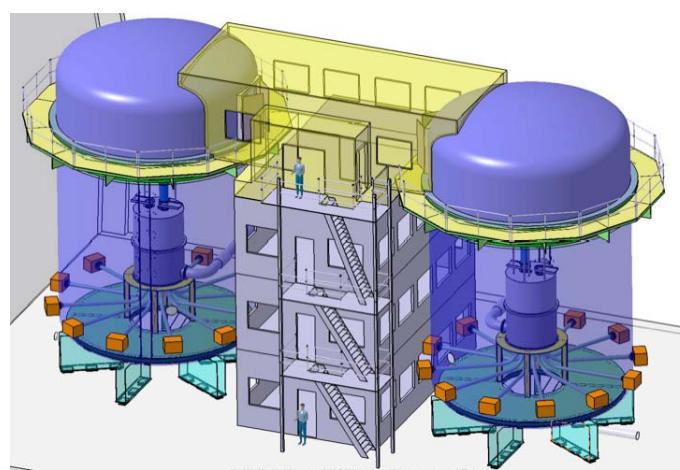
→ H. Kraus (30.07)

To probe $10^{-9} \div 10^{-10}$ pb;
100 kg - 1 ton Cryo detector;
$\sim 10^{-5}$ evt / kg.day

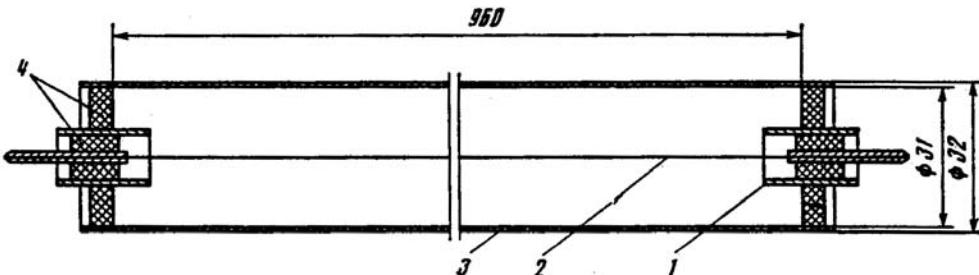
CRESST + EDELWEISS
+ ROSEBUD + ... ;



2 experiments
(different nuclei, different techniques),
e.g. 1 bolometric, 1 noble liquid;



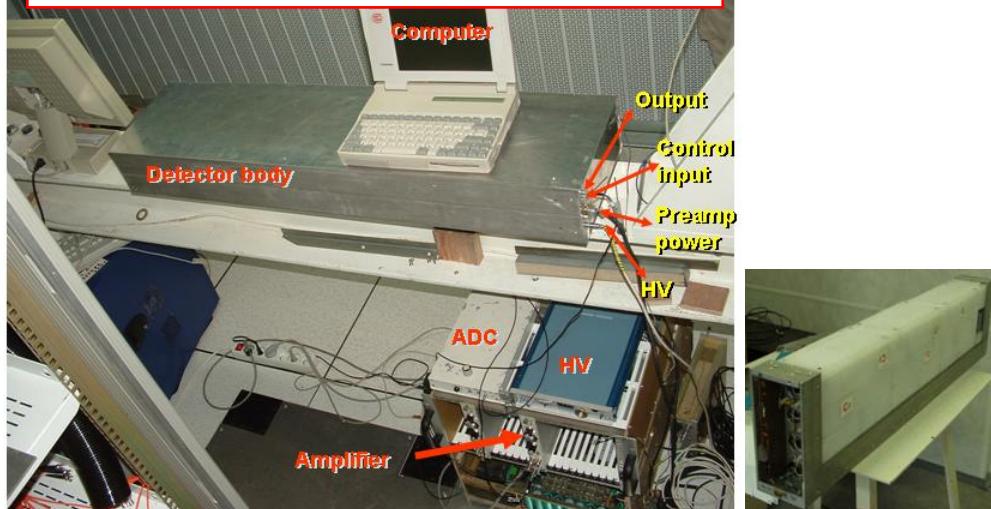
^3He detector (JINR) for the ambient neutrons



- 1 – guard ring;
- 2 – signal wire;
- 3 – body;
- 4 – glass isolators

(covered inside by 50-60 μm Teflon & 1 μm electrolytic Cu against α background)

Fast neutron measurement

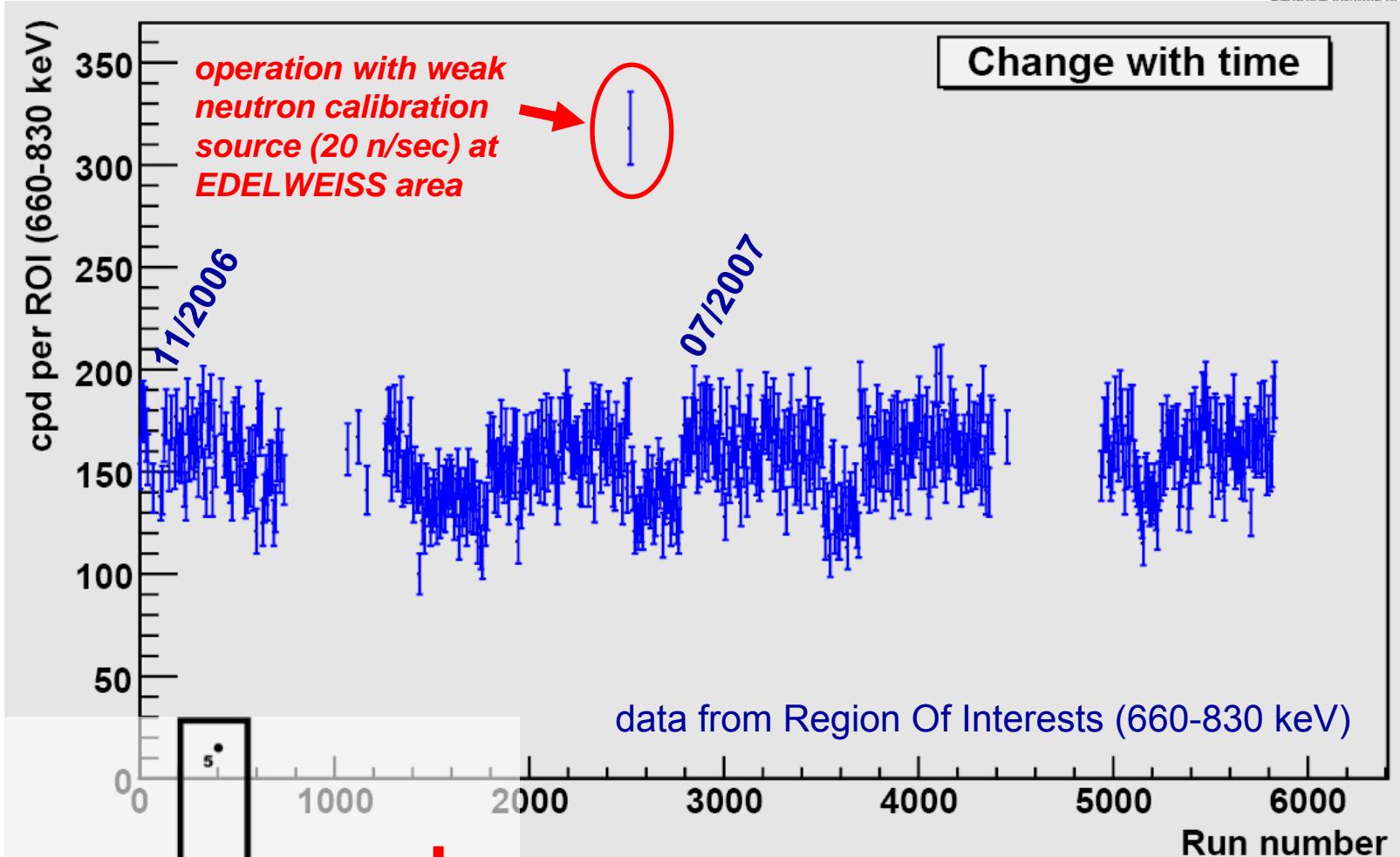


Thermal neutron measurement

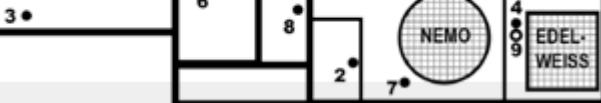


"bare"
Helium-3
counter

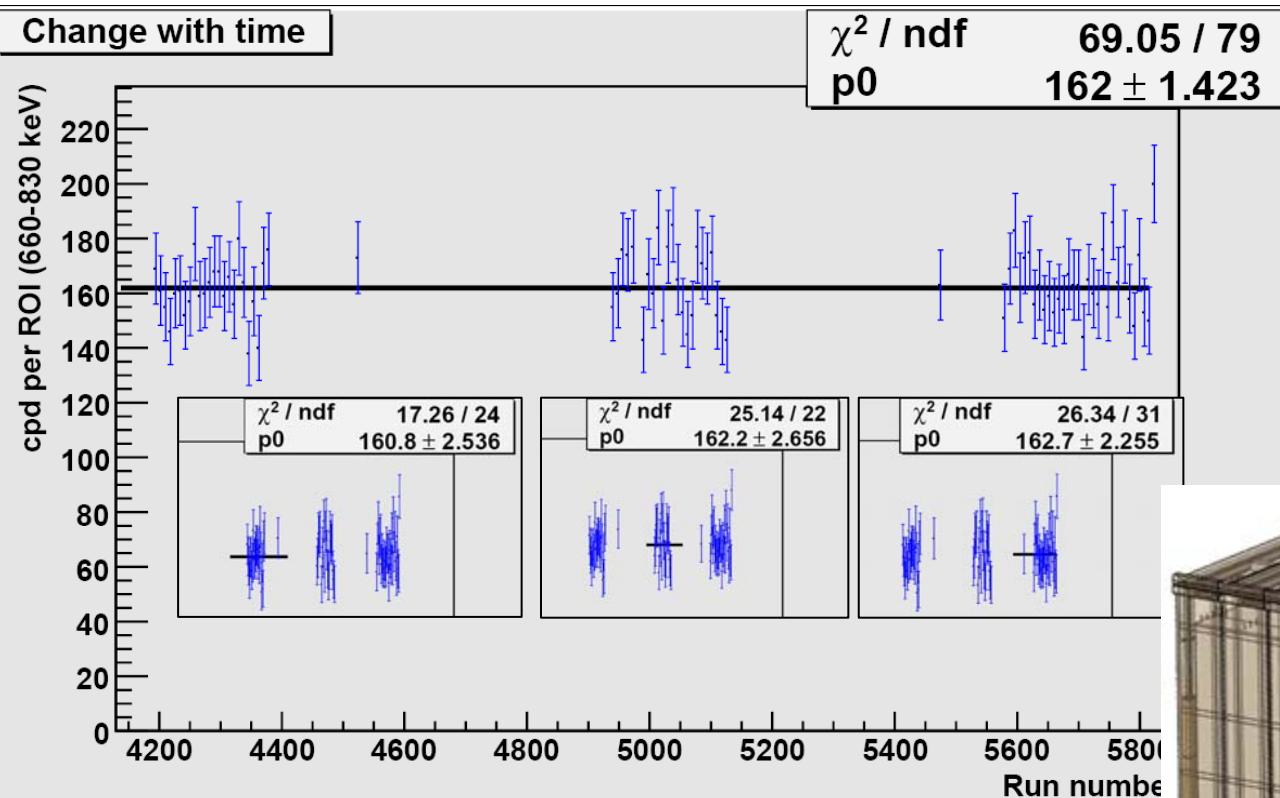
Fast neutron measurement @ LSM (pos.#4)



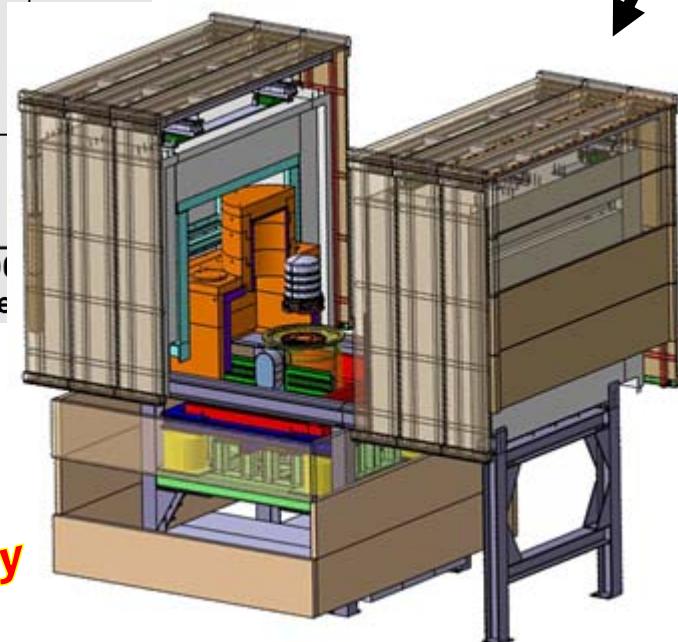
Dependence on a position of the EDW neutron shield(?)



Fast neutron flux in long term measurement



Laser-controlled position of PE shielding since January 2008
→ no fluctuation of the flux observed with fixed geometry

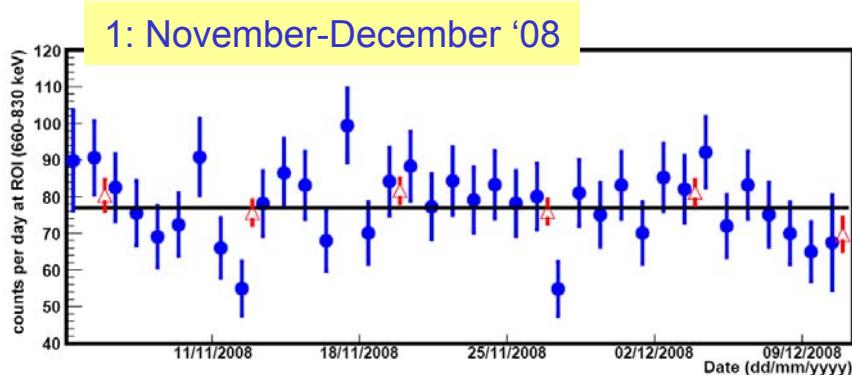


from winter to end of summer 2008:

$\delta\Phi/\Phi(n) < 4\%$ with 90% CL

$162 \text{ n} / \text{day} \Rightarrow \Phi = 5.3 \times 10^{-6} \text{ n} / \text{cm}^2 / \text{s}$ *preliminary*

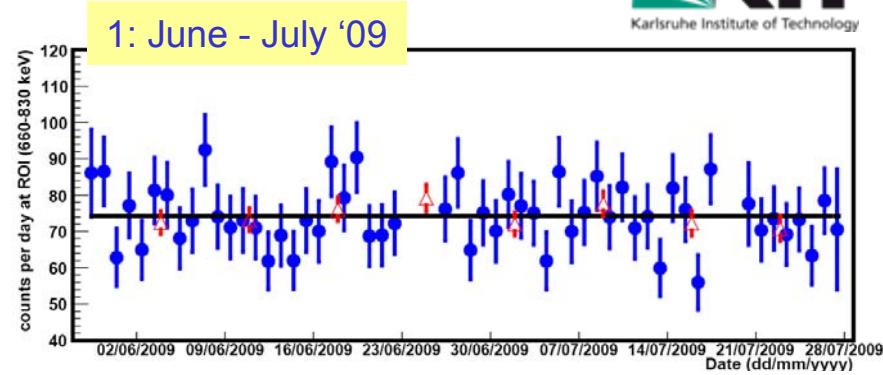
Thermal neutrons: „bare“ detectors



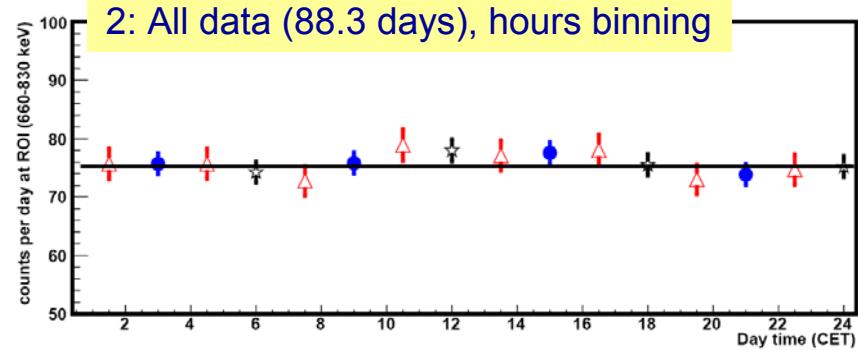
❖ EDW area, *outside the shields*

1. No seasonal effect (1.3σ);
2. No day / night fluctuations;
3. $\Phi = (3.57 \pm 0.05^{\text{stat}} \pm 0.27^{\text{syst}}) \cdot 10^{-6} \text{ n/cm}^2/\text{s}$

arXiv:1001.4383v1



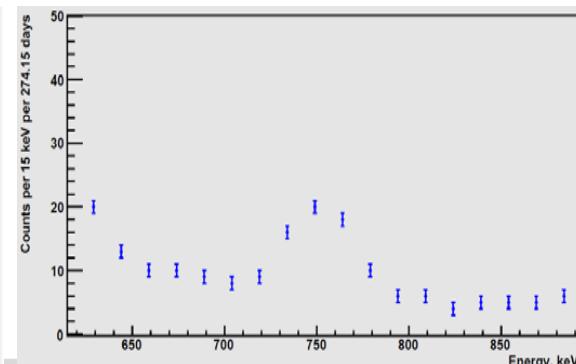
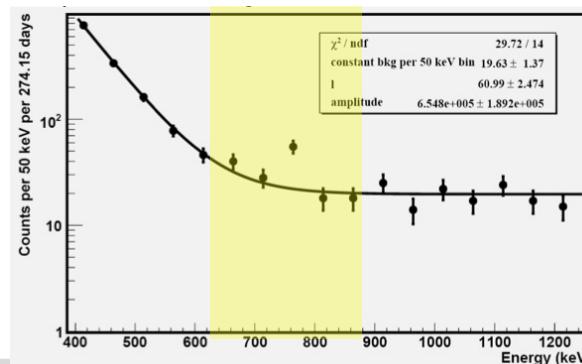
2: All data (88.3 days), hours binning



❖ EDW area, *inside the shields*
(274 live days)

$$\Phi = (7.3 \pm 1.8) \cdot 10^{-9} \text{ n/cm}^2/\text{s}$$

preliminary



Strong AmBe source ($2 \cdot 10^5$ n/s)

Efficiency of Edelweiss shield was checked with strong AmBe ($\sim 10^5$ n/s) source in middle of March'10.

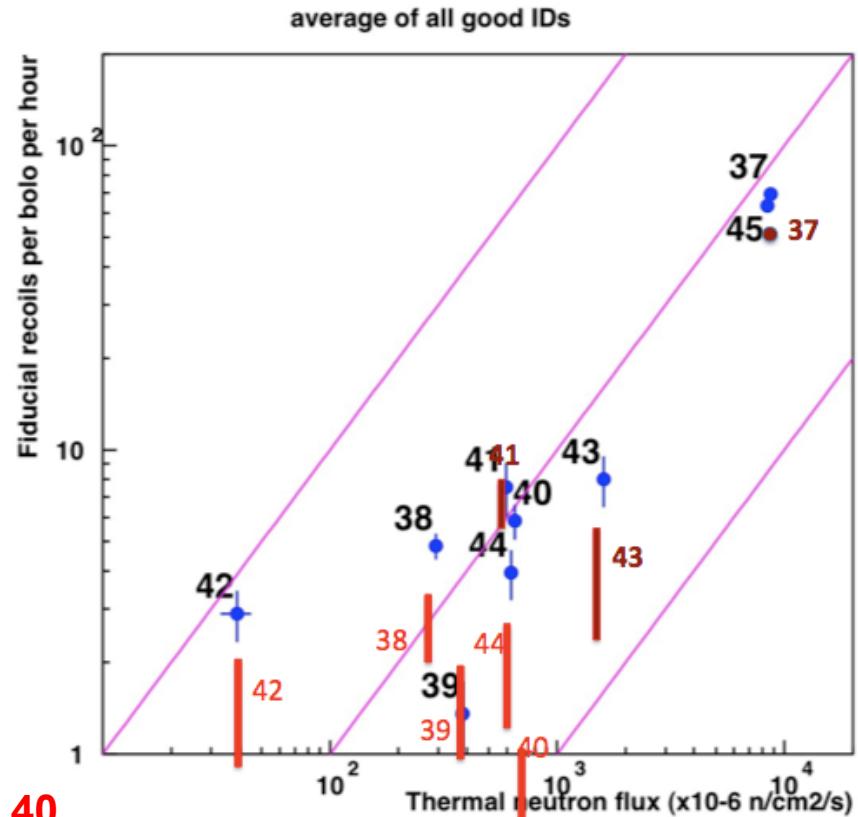
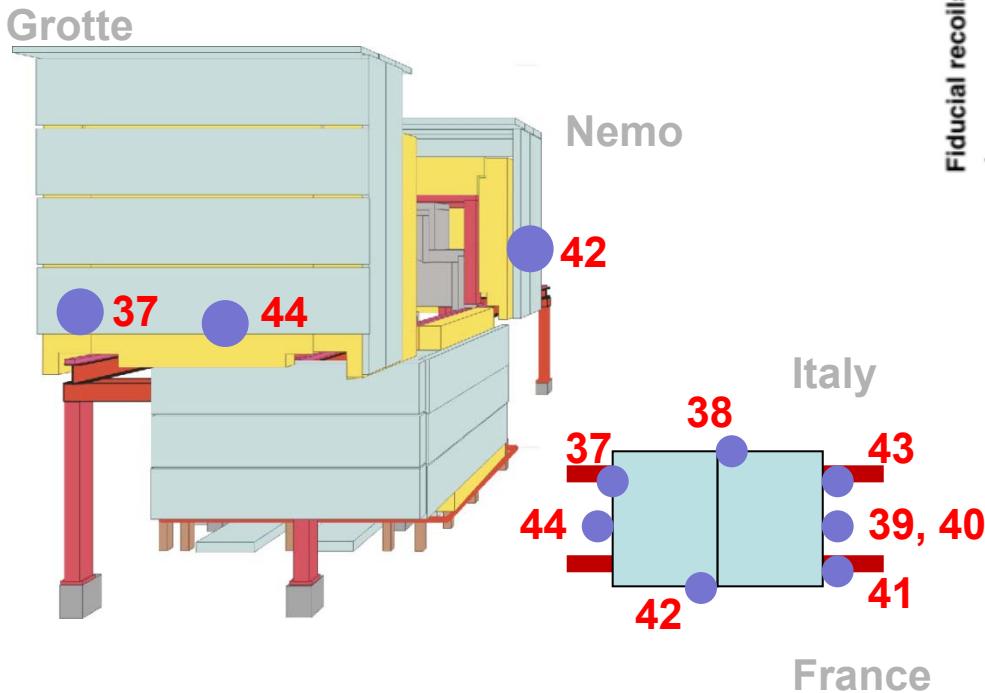
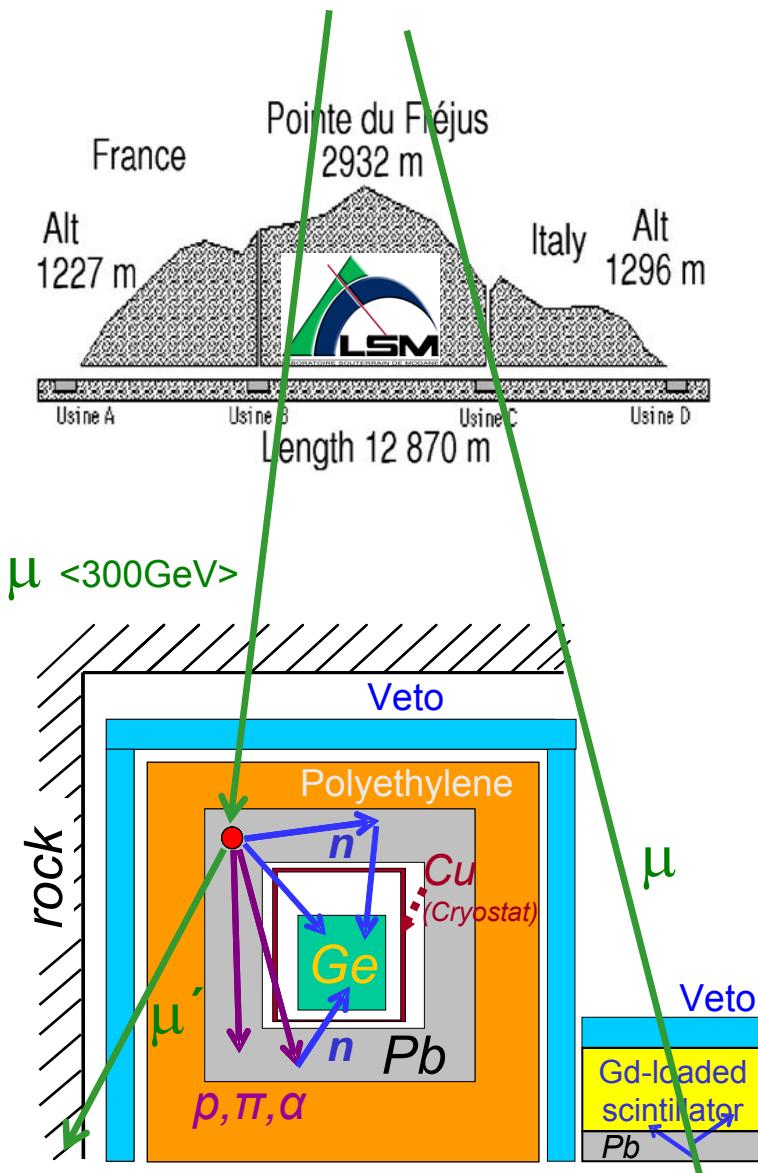
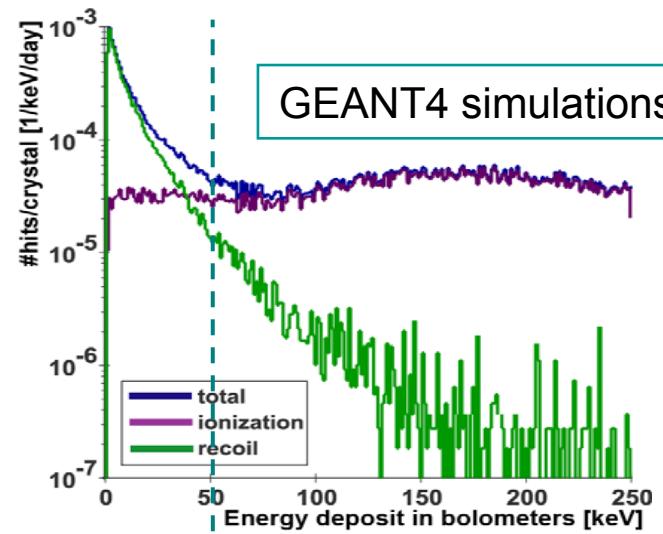


Fig. Correlation of thermal neutron flux between ${}^3\text{He}$ detector placed near the cryostat and Ge bolometers of EDELWEISS. In red are simulated data (GEANT4).

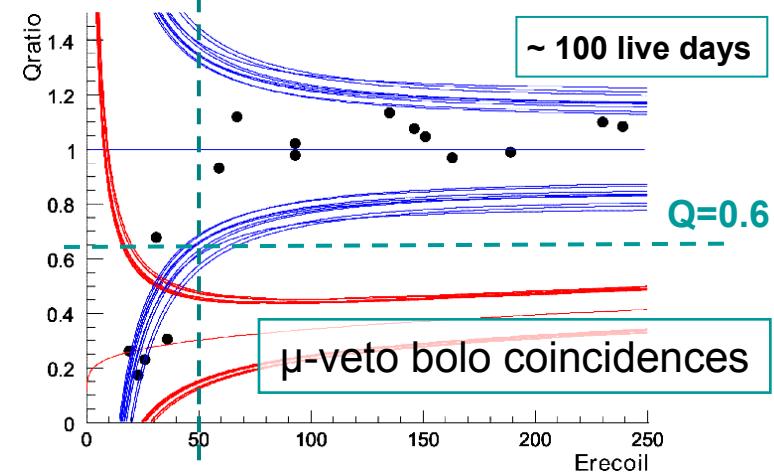
μ -induced background study



1.



2.

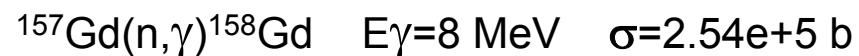
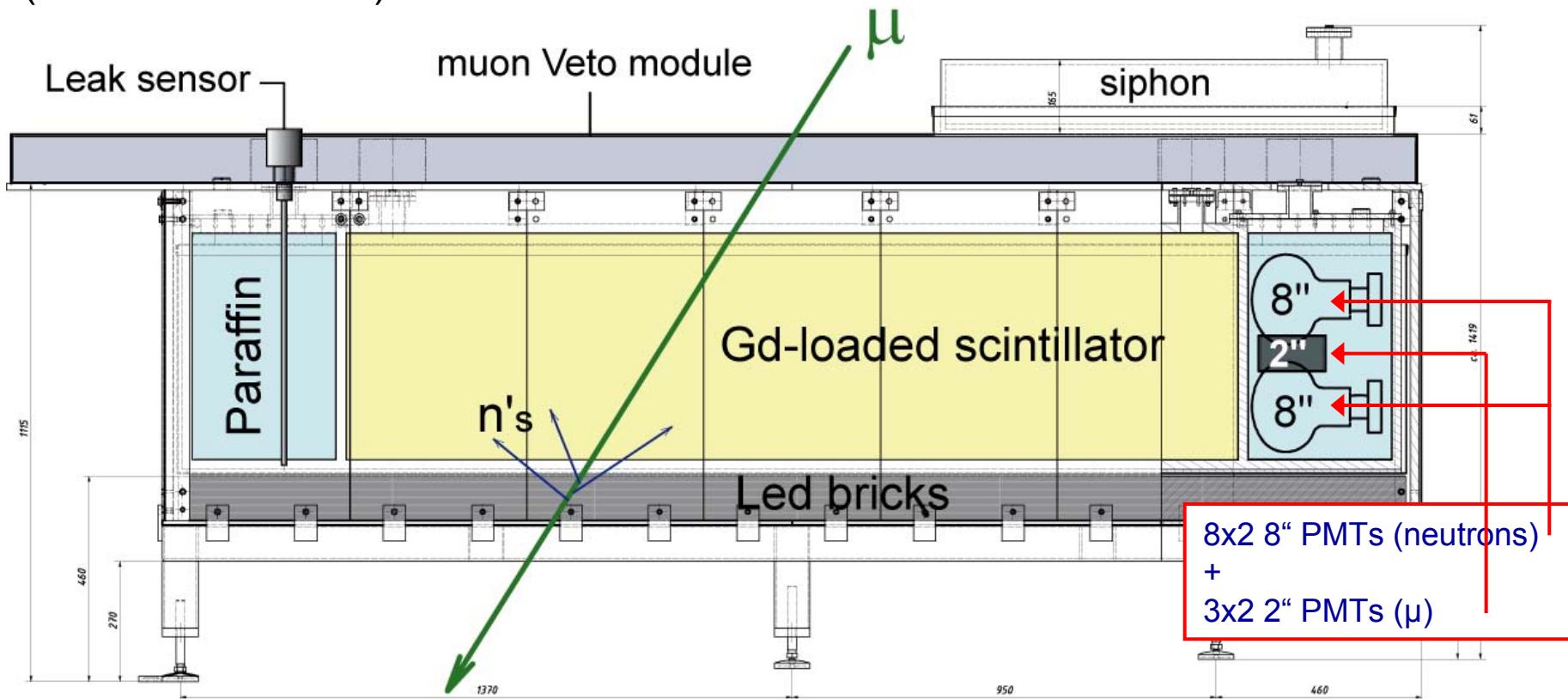


3.

Dedicated measurements

μ -induced neutrons: neutron counter

Dimensions (H x W x L):
(50 x 100 x 200 cm)

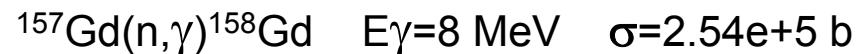
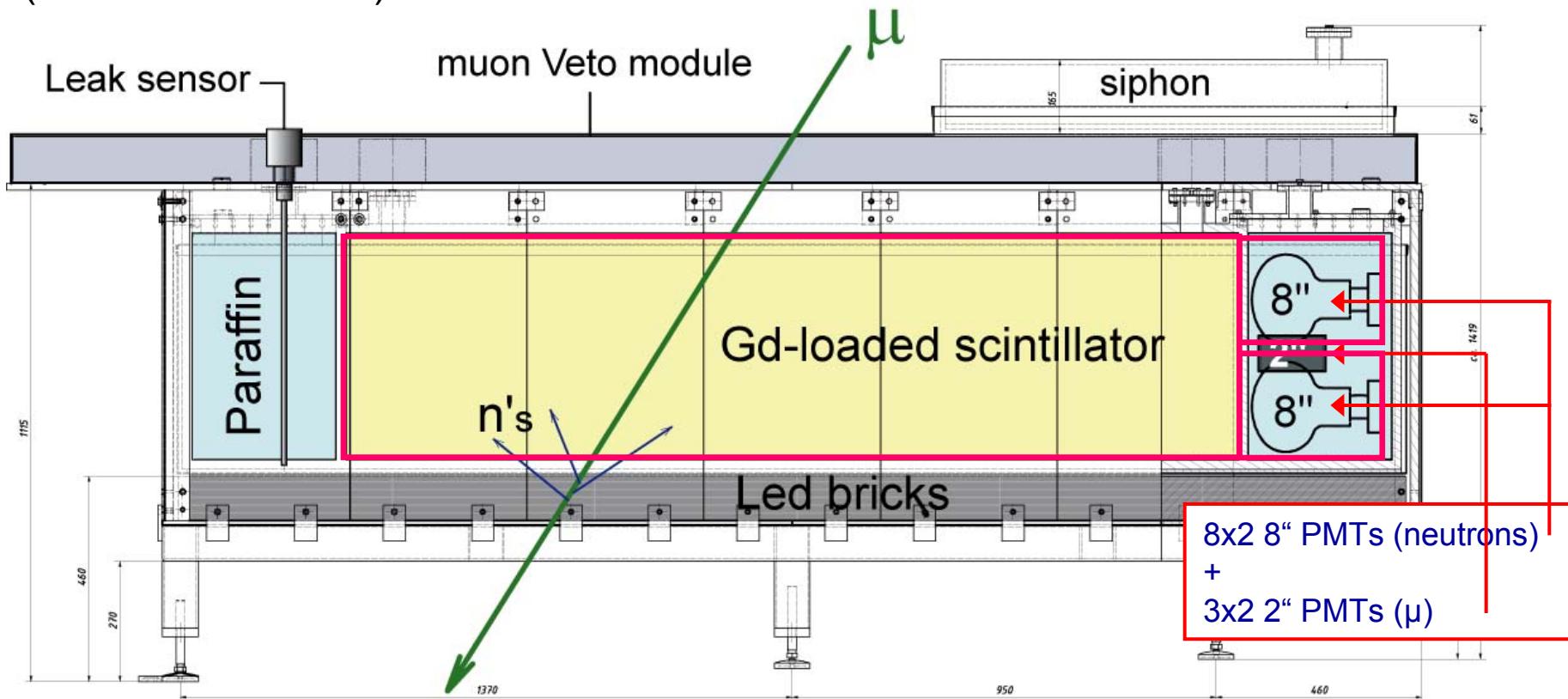


Signature: μ -n coincidence or multiple n's

Neutron count rate: ~1 /day (μ)

μ -induced neutrons: neutron counter

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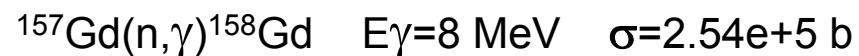
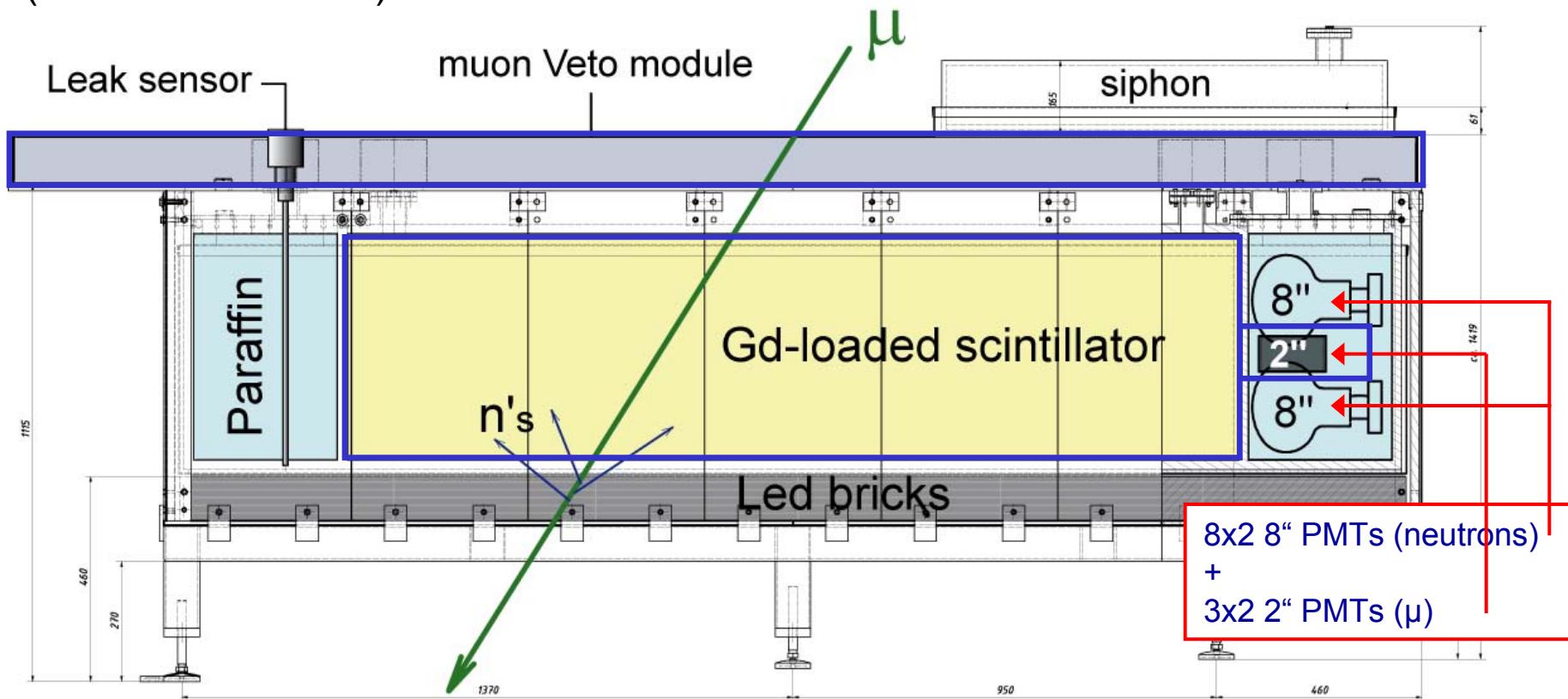


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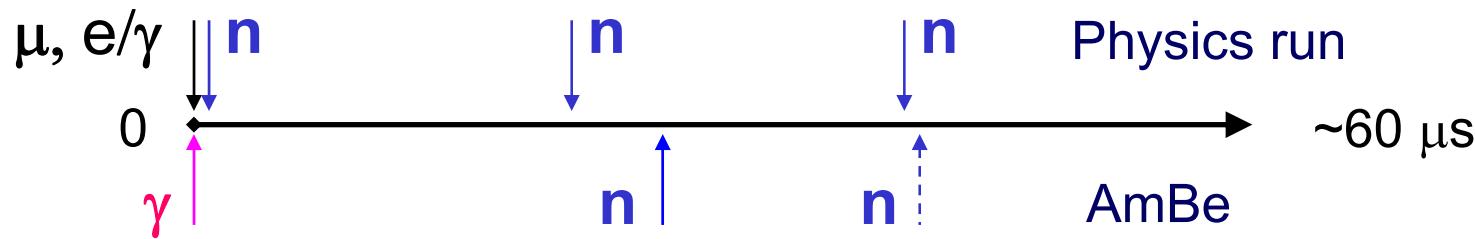


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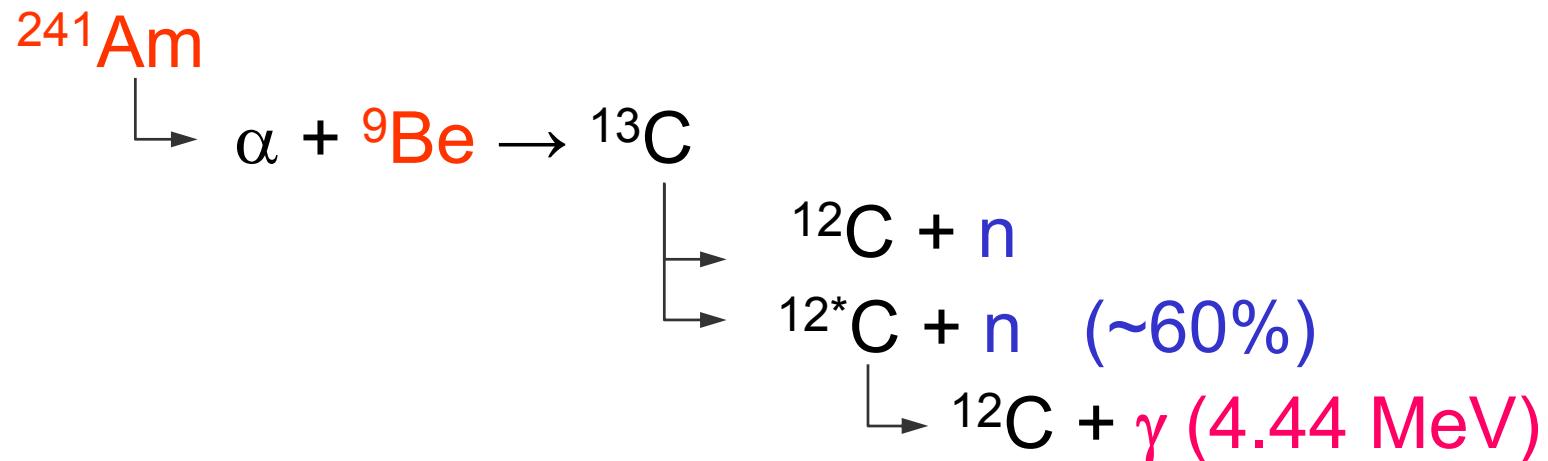
Neutron count rate: ~1 /day (μ)

μ -induced neutron: measurement scheme

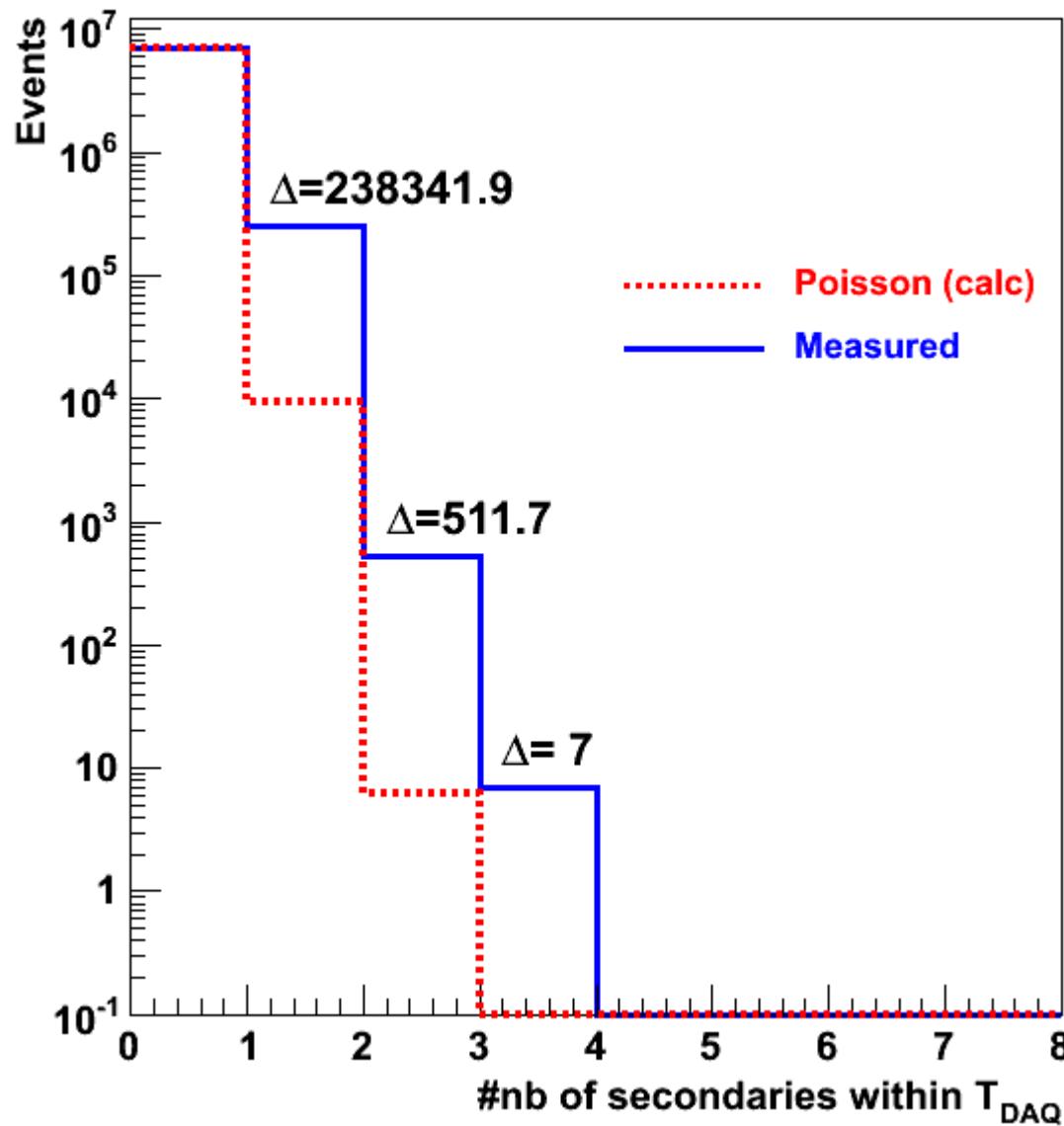
DAQ time window:



AmBe source: $n + \gamma$



Neutron counter: AmBe neutron measurement

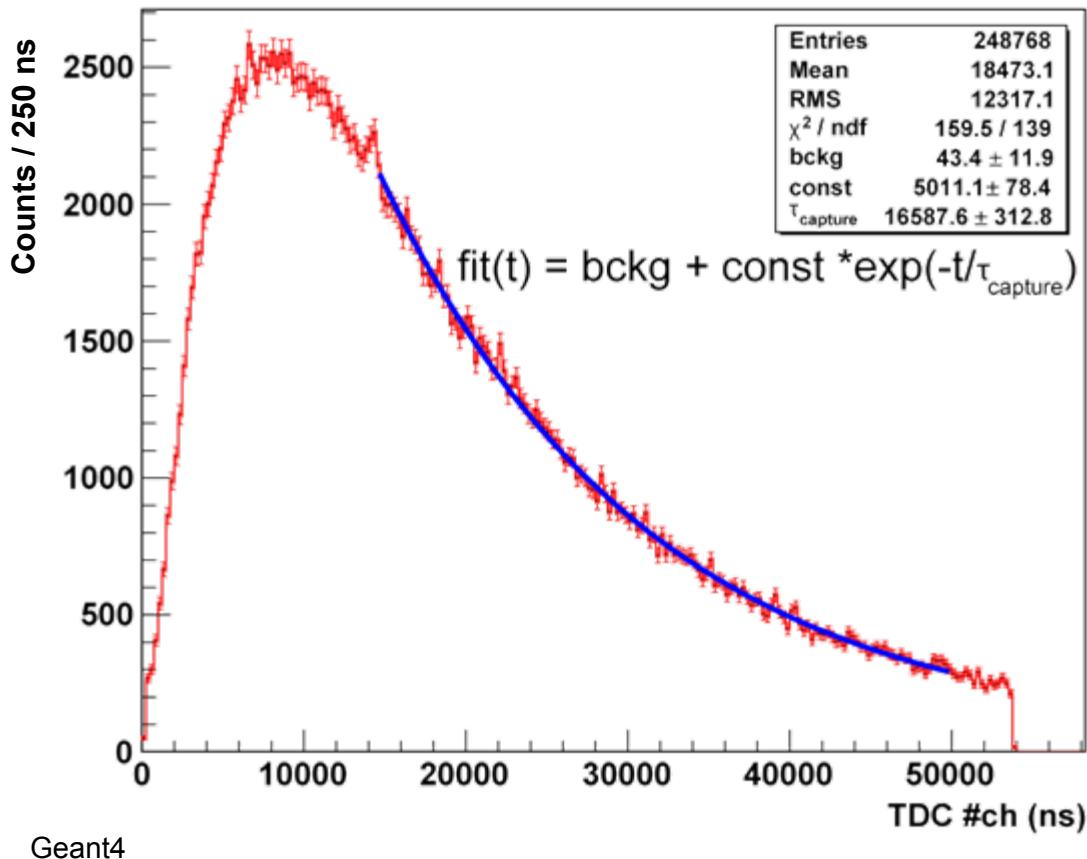


$\sim 3,94$ days

Neutron source ~ 20 n/s,

$T_{\text{daq}} = 53.4 \mu\text{s}$

AmBe neutron measurement: Δt

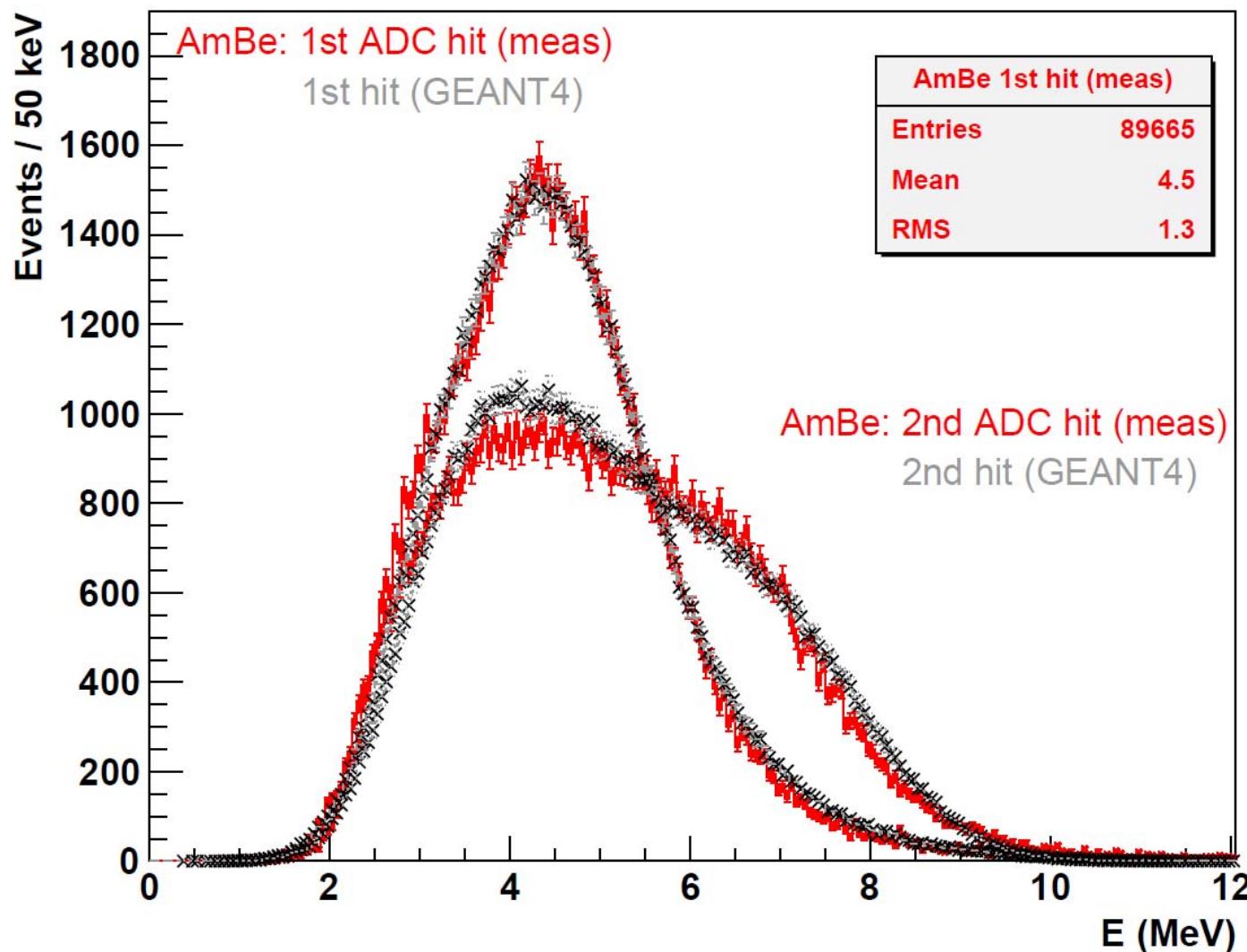


Geant4

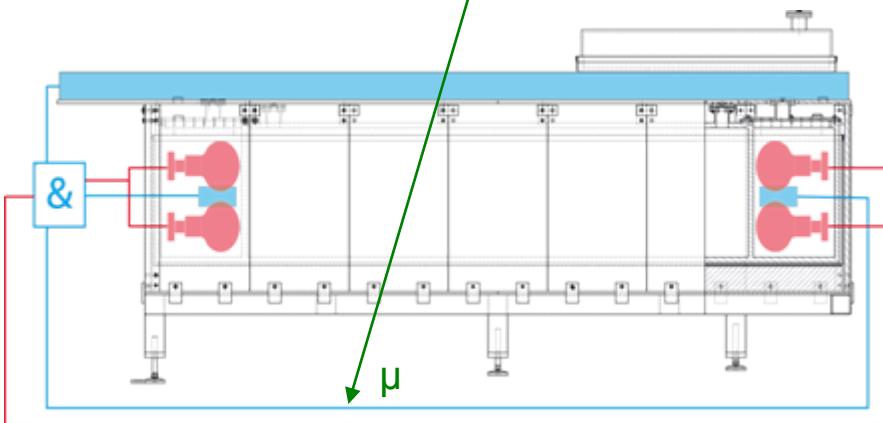
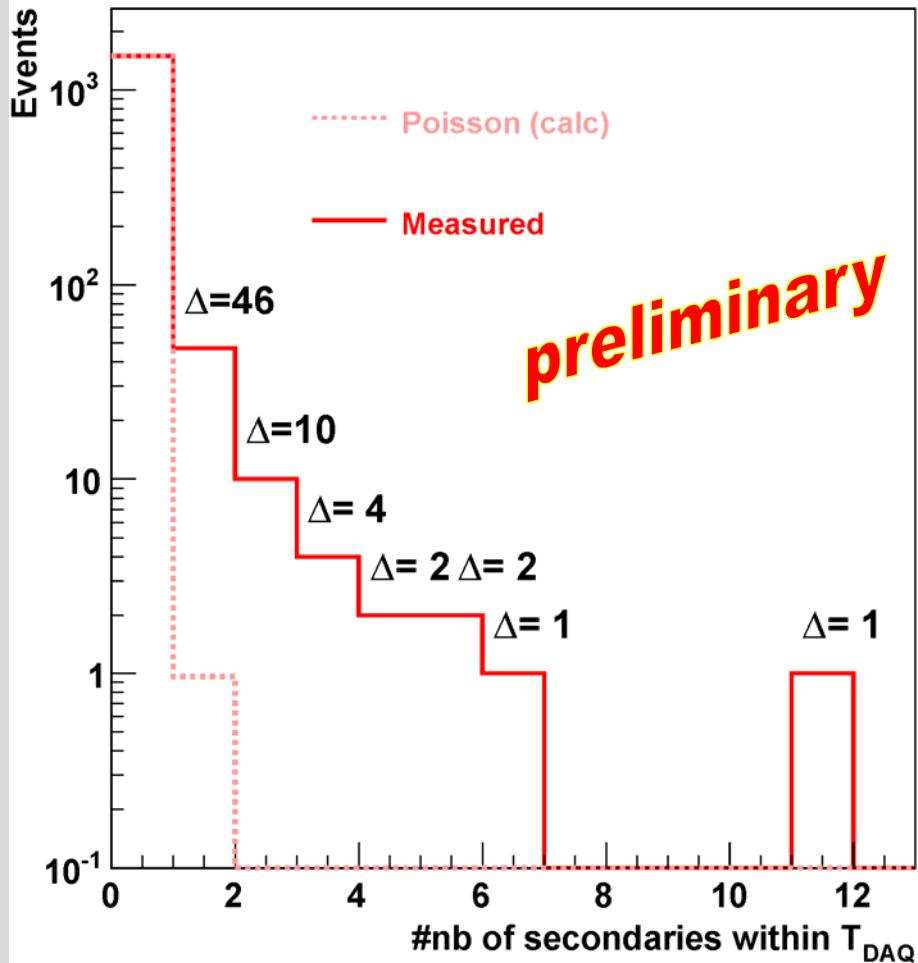
Gd content, %	0.18	0.19	0.20	0.21	0.22
$\tau_{capture}$, ns	17800	17100	16290	15600	15000
$\Delta\tau_{capture}$, ns	± 100	± 100	± 90	± 80	± 80

- AmBe source: ~20 n/s
- E_n up to ~11 MeV, mean energy at ~4 MeV
- Mean capture time on Gd: **19 μ s**
- Capture time constant: **$16.6 \pm 0.3 \mu$ s**
- Agreement with Geant4

AmBe measurement + GEANT4



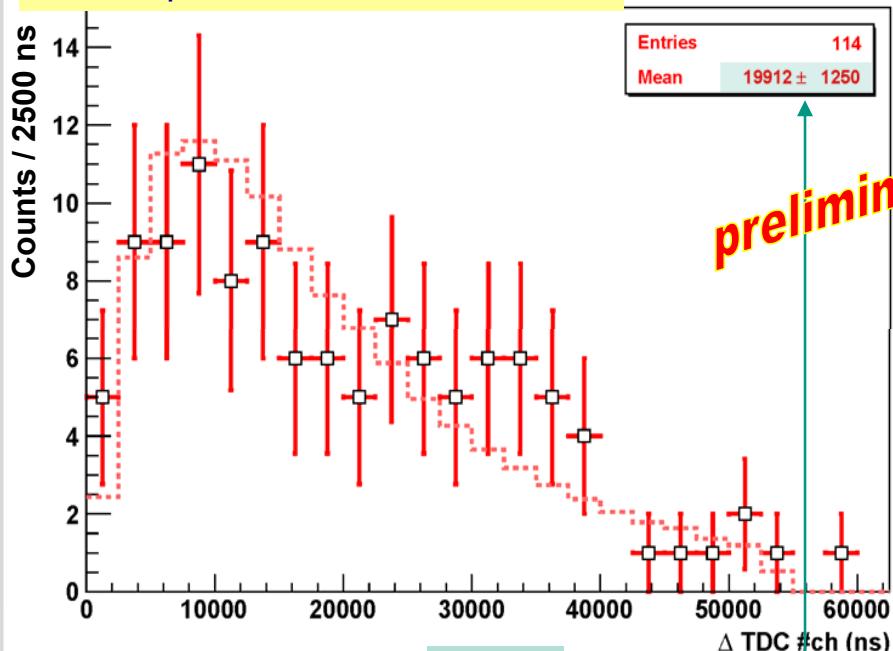
Coincidence with μ -veto system: secondaries



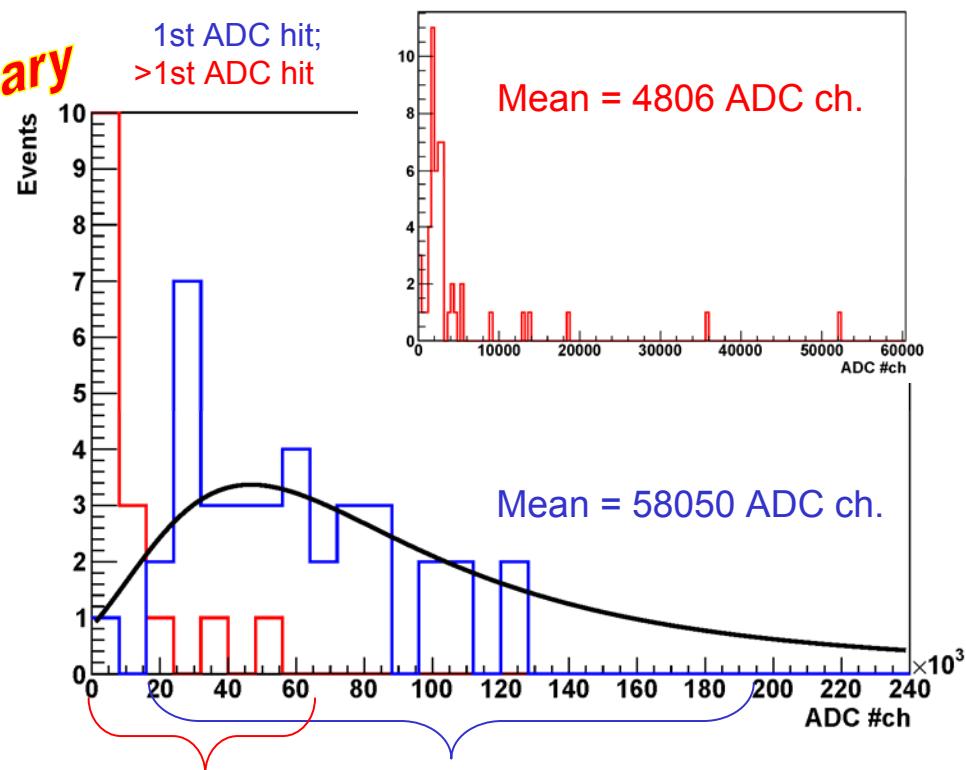
- Coincidence between μ -detector and neutron counter
 - $T_{DAQ}=60 \mu\text{s}$
 - ~ 288 live days
- Registered muons: 1564
- $N_{\text{event}} (\geq 1 \text{ secondary}) = 67$
- $N_{\text{secondaries}} = 114$
- $t_{\text{hit}} > 1000 \text{ ns} + \Delta t > 200 \text{ ns}$ to avoid PMT after-pulses

Coincidence with μ -veto system: Δt_{sec} , energy

ΔTDC spectrum, at least 2 hits:



Energy deposit, at least 2 hits:

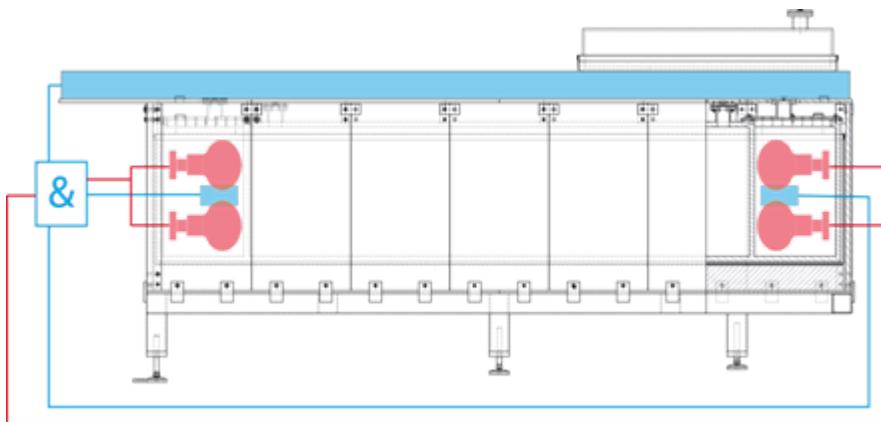
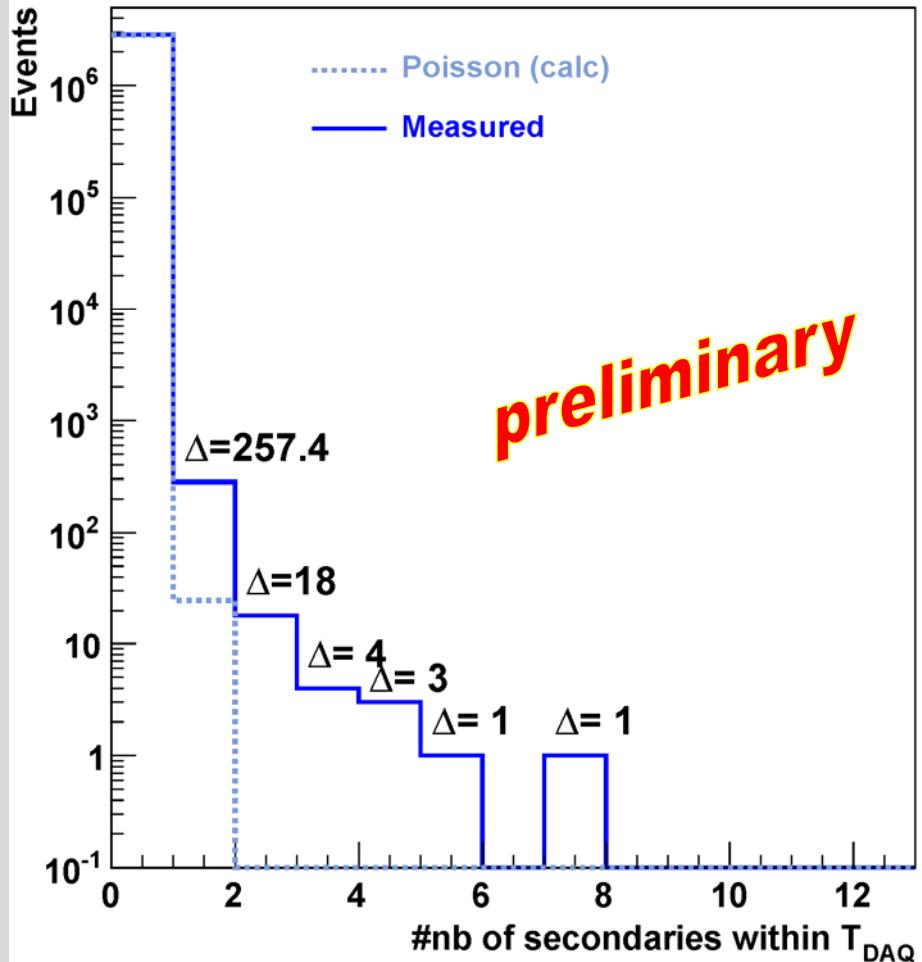


Delayed n's,
predominately
low energy deposit

Prompt μ 's,
 ~ 100 MeV energy deposit

→ Candidates for μ induced n's !

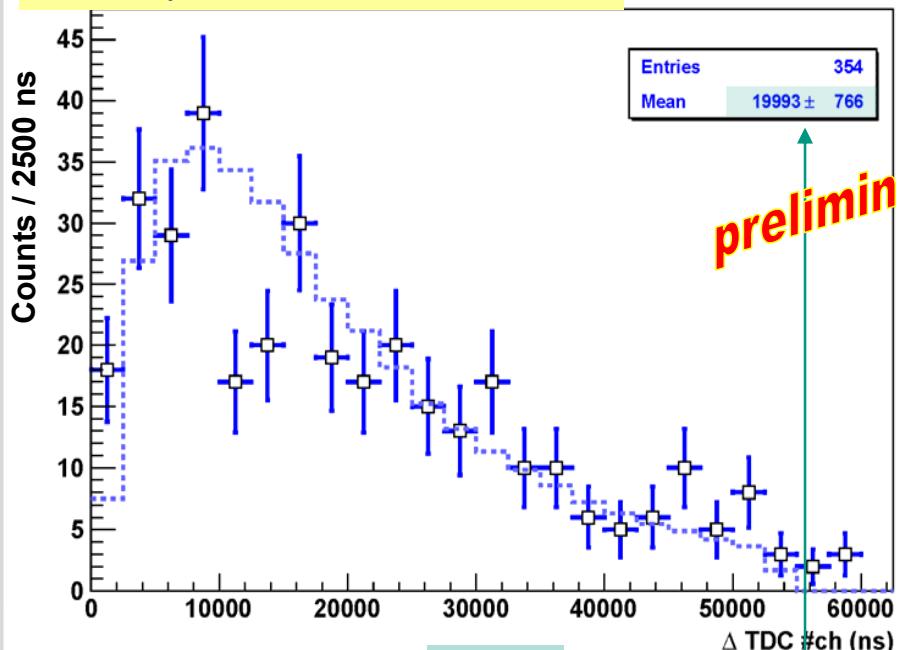
NC selection: multi-hit



- Multi-hit events in **neutron counter**
- PMT adapted gain
- $T_{DAQ}=60 \mu s$
- ~ 254 live days
 - $N_{event} (\geq 1 \text{ secondary}) = 309$
 - $N_{secondaries} = 354$
- $t_{hit} > 1000 \text{ ns} + \Delta t > 200 \text{ ns}$ to avoid PMT after-pulses

NC selection, multi-hit : Δt_{sec} , energy

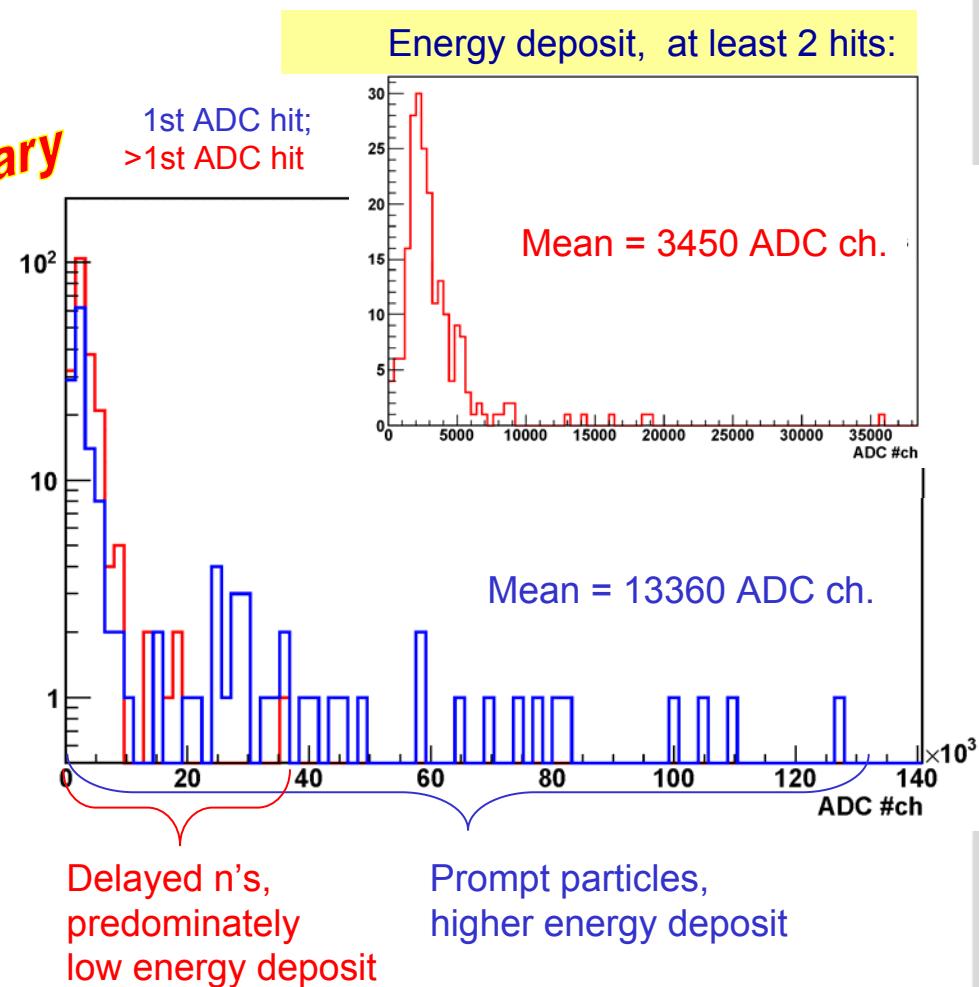
ΔTDC spectrum, at least 2 hits:



- $\langle \Delta t_{sec}(\text{AmBe}) \rangle = 19 \mu\text{s}$
- ~ 254 live days
- $t_{hit} > 1000 \text{ ns} + \Delta t > 200 \text{ ns}$ to avoid PMT after-pulses
- Kolmogorov-Smirnov test (unbinned data): $prob = 0.11$

→ Candidates for μ induced n's !

Energy deposit, at least 2 hits:



Summary

- ✓ Ambient neutrons:
 - Fast component: measurement campaign 2006-2008;
 - Thermal neutrons:
outside of the shields: different places are measured, [arXiv:1001.4383v1](https://arxiv.org/abs/1001.4383v1)
monitoring inside of the shields;
 - ✓ Strong AmBe calibration \Leftrightarrow MC normalized;
 - ✓ Muon-induced neutrons:
 - Neutrons from AmBe are seen;
 - Candidates for μ induced n's, $\mathcal{O}(1 \text{ neutron / day})$, >250 live days;
 - Proof-of-principle article in press in Astropart.Phys.
([doi:10.1016/j.astropartphys.2010.06.001](https://doi.org/10.1016/j.astropartphys.2010.06.001), [arXiv:1006.3098v1](https://arxiv.org/abs/1006.3098v1))
- => Road to 1 ton experiment, **EURECA**

The EDELWEISS Collaboration



Collaboration meeting X.2009 @KIT

≈ 50 persons (30 FET);
11 PhD theses;
4 post-docs;
4 countries

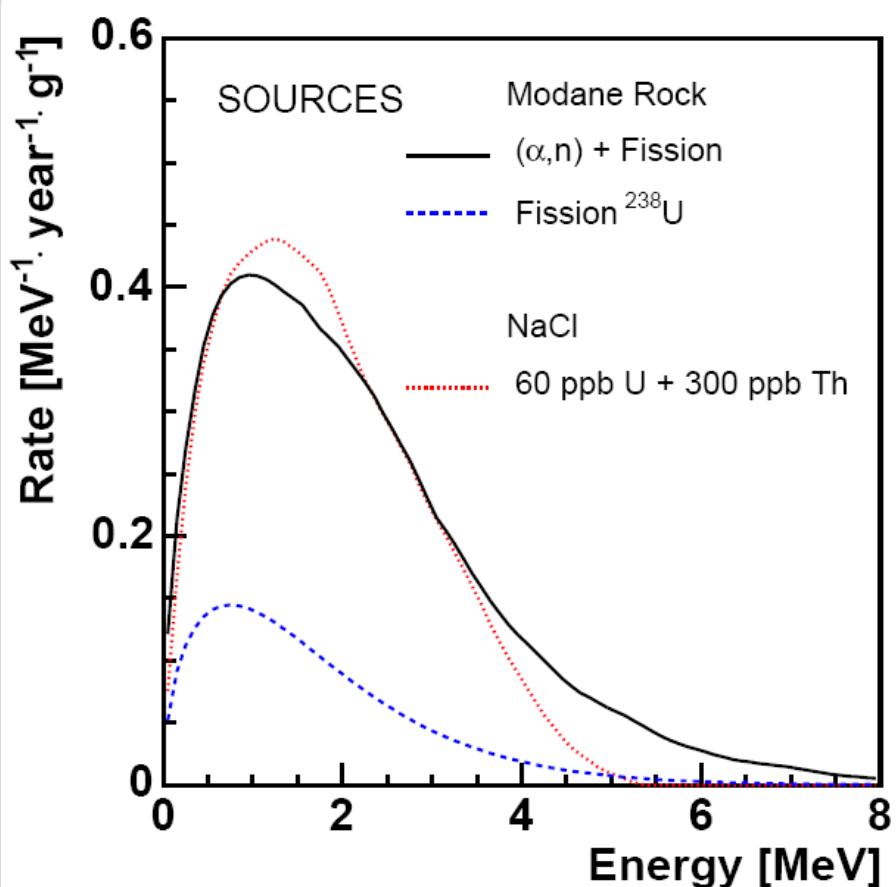


- CEA Saclay (IRFU & IRAMIS)
- CSNSM Orsay
- IPN Lyon
- Institut Néel Grenoble
- KIT: IK, IEKP (+IPE 2011) Karlsruhe
- JINR Dubna
- Oxford University
- Sheffield University
- Detectors, electronics, acquisition, data handling, analysis
- Detectors, cabling, cryogenics
- Electronics, cryo, low radioactivity, analysis, detectors, MC
- Cryogenics, electronics
- Veto, neutron detector, background, analysis, electronics
- Background, neutron, radon monitors
- since 2009: Detectors, cabling, cryogenics, analysis
- since 2010: MC simulations

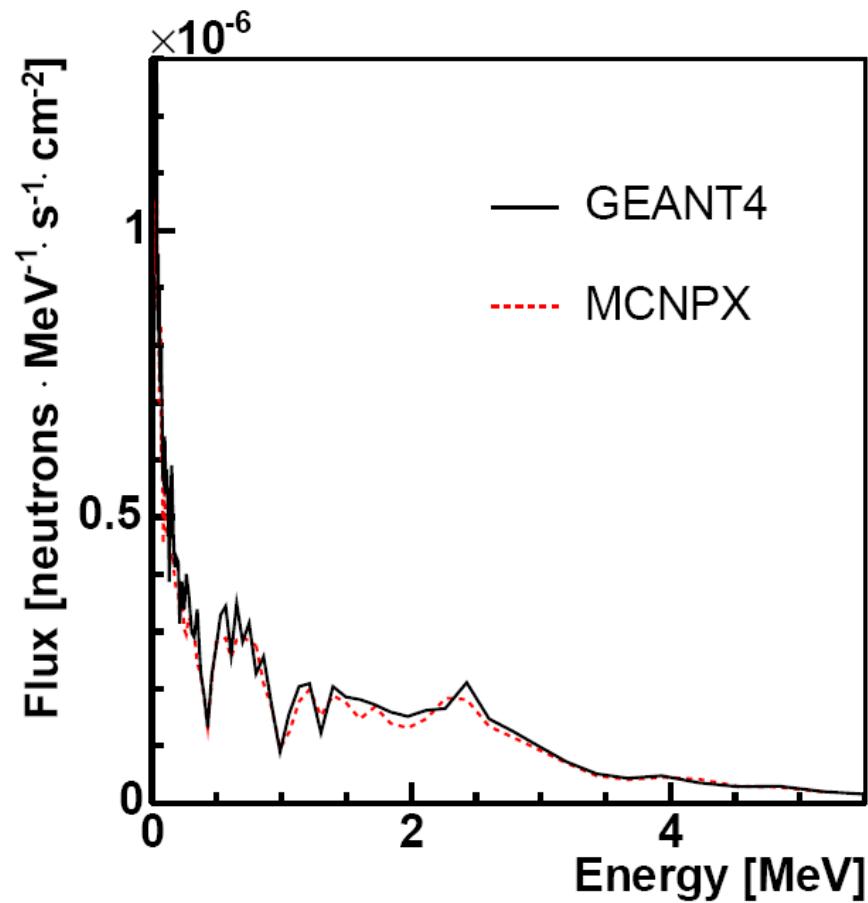
ADDITIONAL SLIDES

Ambient neutron spectra simulated for LSM

R. Lemrani et al., Nucl.Instrum.Meth. A560 (2006) 454-459



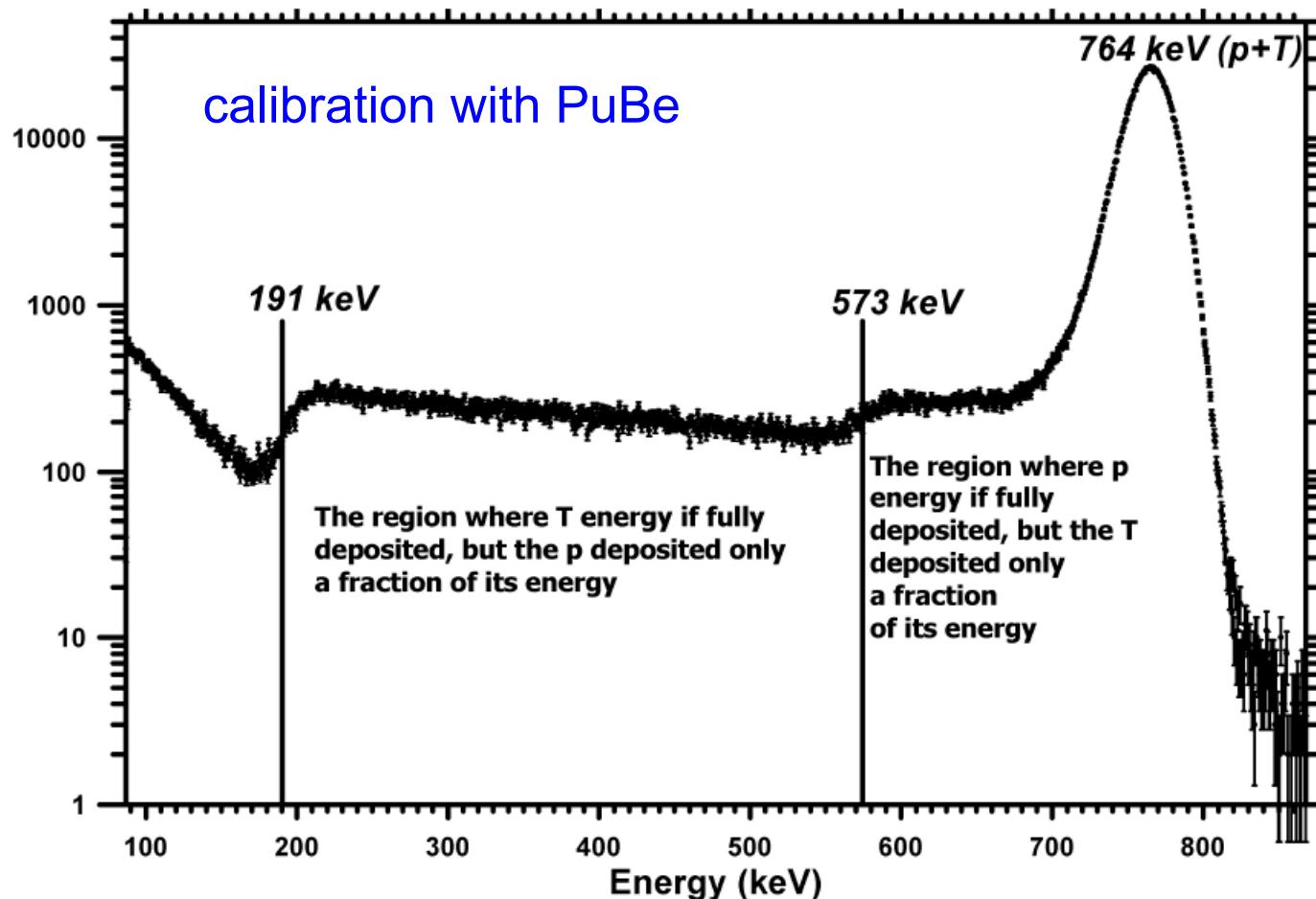
simulated neutron spectrum from
U and **Th** traces **in the Modane rock**



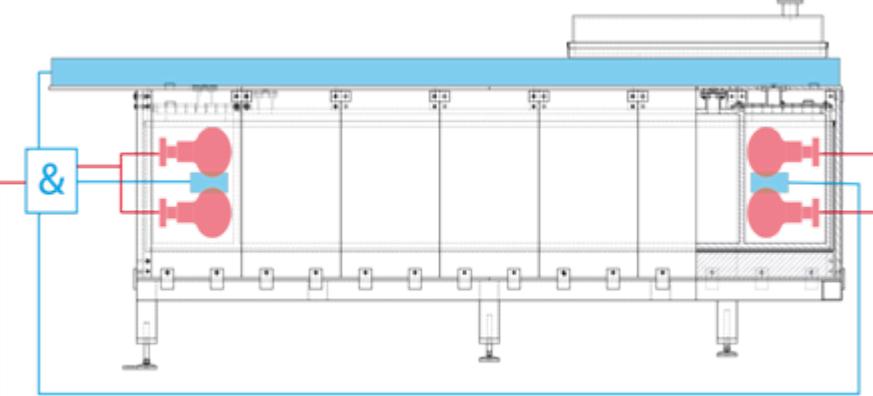
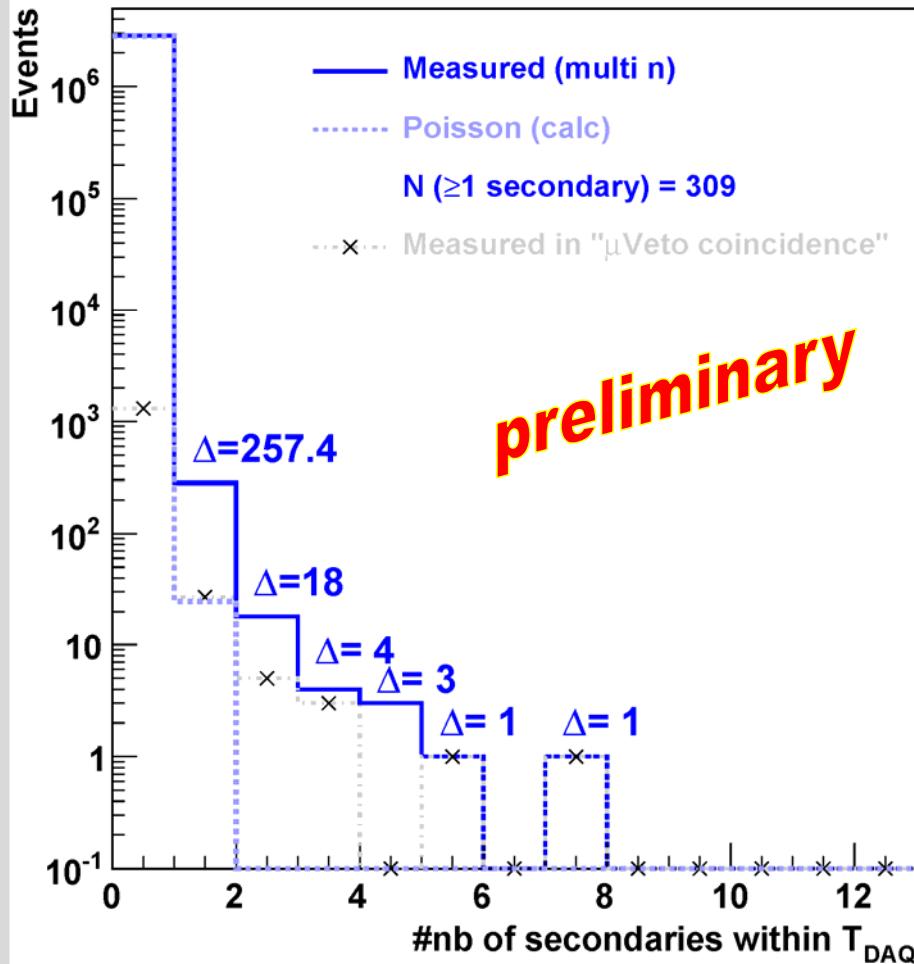
simulated neutron energy spectra
at LSM rock boundary

Neutron capture spectrum, ${}^3\text{He}$ detector

$\text{n} + {}^3\text{He} \rightarrow \text{p} + \text{T}$ ($\sigma_p = 5333(7)$ b) $Q = 764$ keV



Neutron counter selection: multi-hit



- Multi-hit events in neutron counter
- PMT adapted gain
- $T_{\text{DAQ}}=60 \mu\text{s}$
- ~254 live days
- $N_{\text{event}} (\geq 1 \text{ secondary}) = 309$
- $N_{\text{secondaries}} = 354$
- $t_{\text{hit}} > 1000 \text{ ns} + \Delta t > 200 \text{ ns}$ to avoid PMT after-pulses