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A novel neutron detector for 3-He replacement in environmental applications

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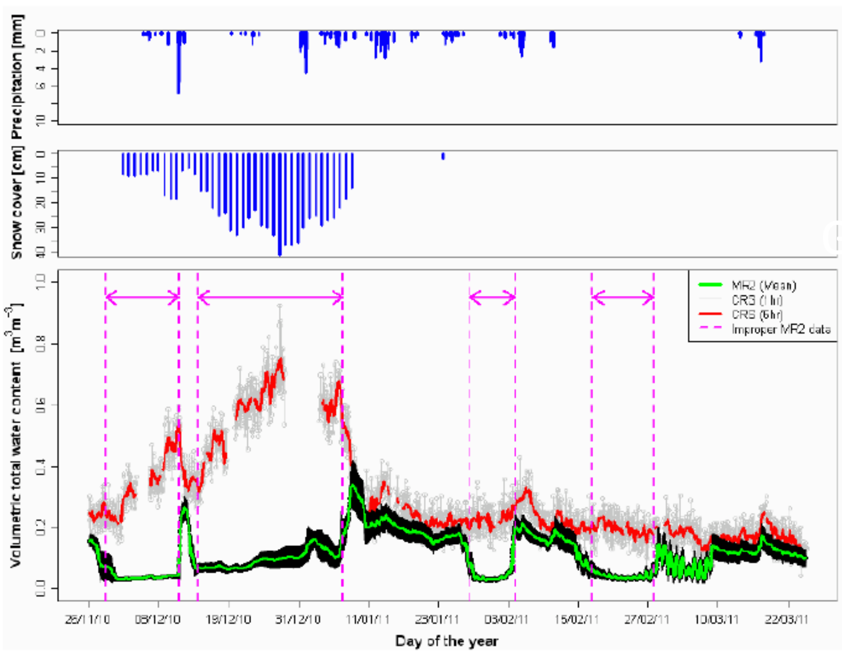
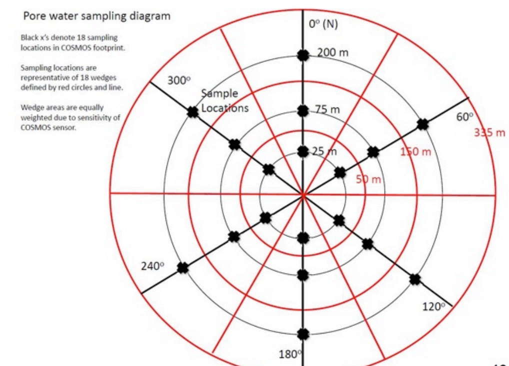
Neutrons as soil moisture probe
Cosmic Ray Neutron Sensing

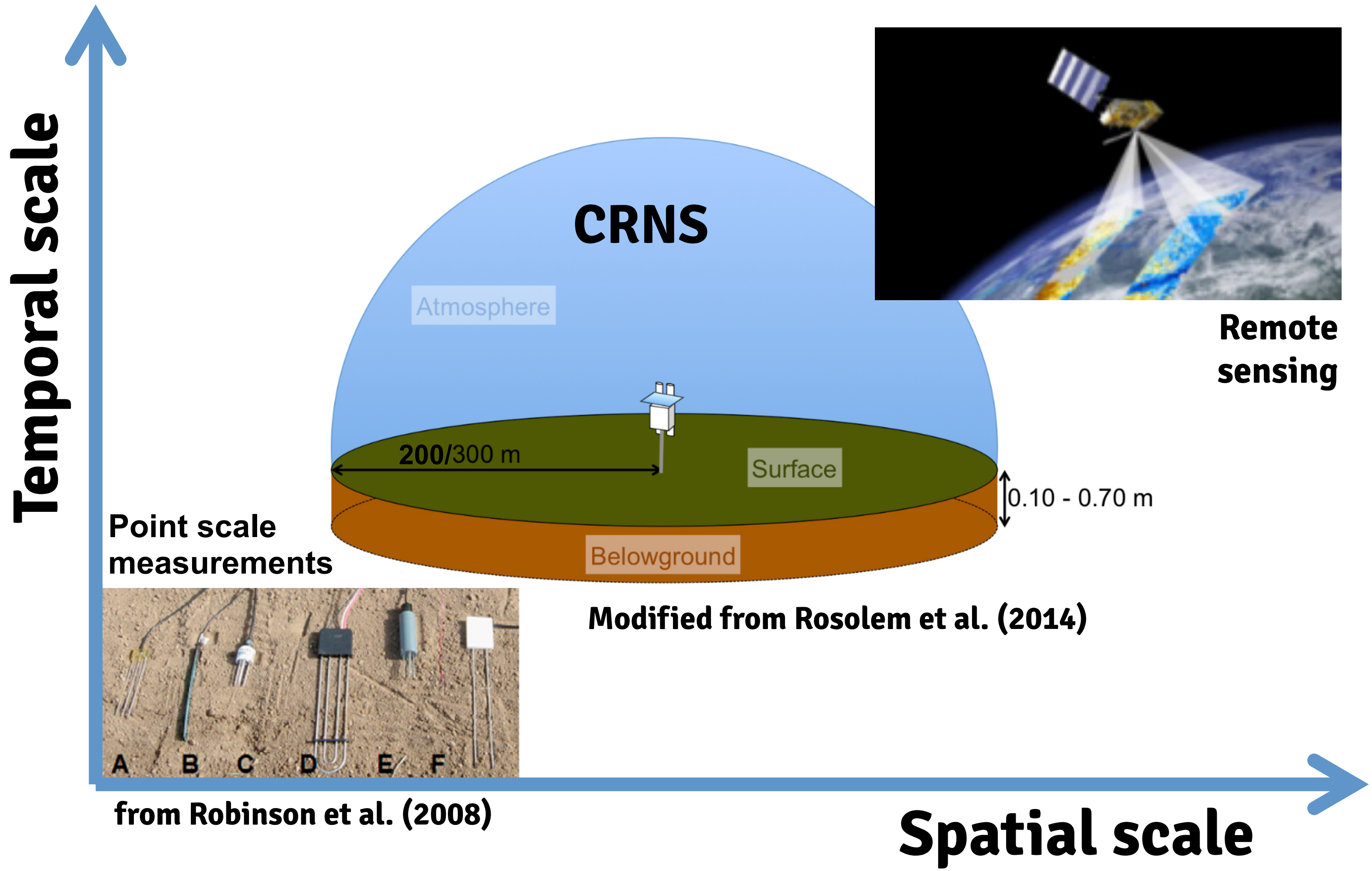


$$\theta_{CRS} = \left(\frac{a_0}{\frac{N}{N_o} - a_1} - a_2 \right)$$



Due to their high content of hydrogen, water molecules are a good natural moderator. The (epi)thermal neutron flux at ground compared to incoming neutron flux provides an estimate of the soil moisture averaged over a large volume of terrain

Cosmic Rays Neutron Sensing



Modified from Rosolem et al. (2014)

from Robinson et al. (2008)

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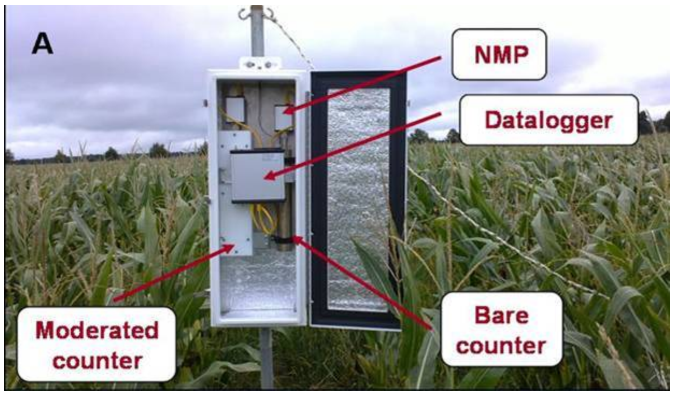
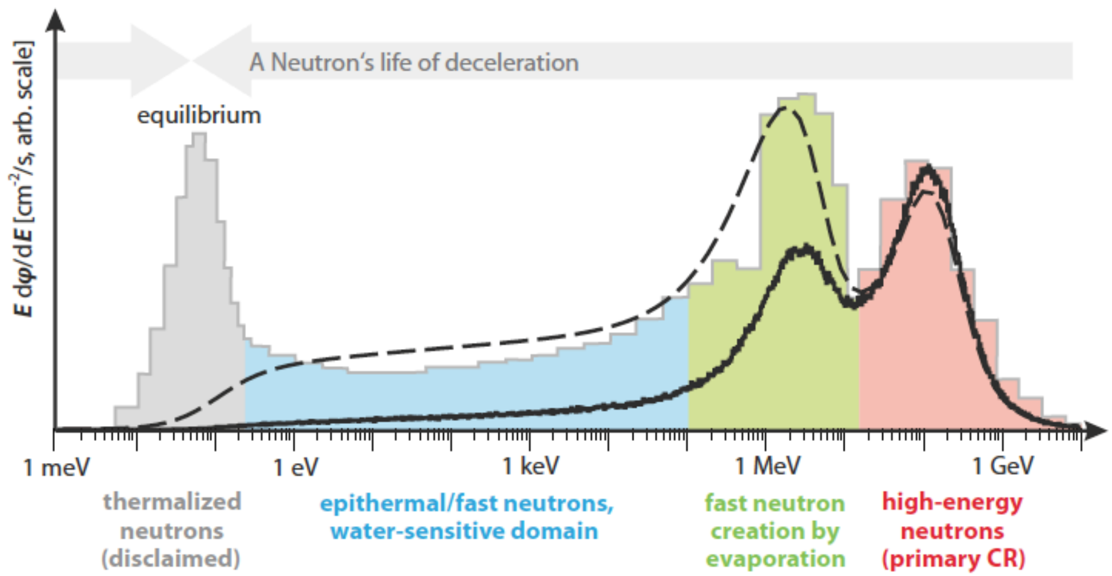
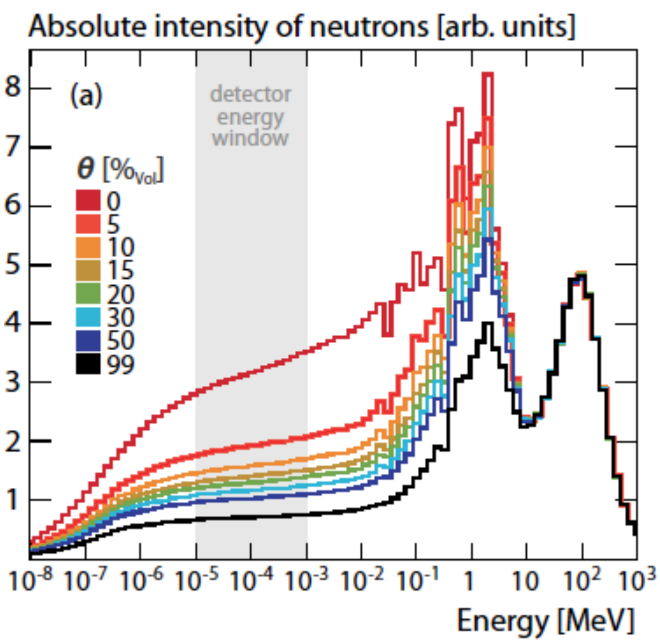
Applications GANS







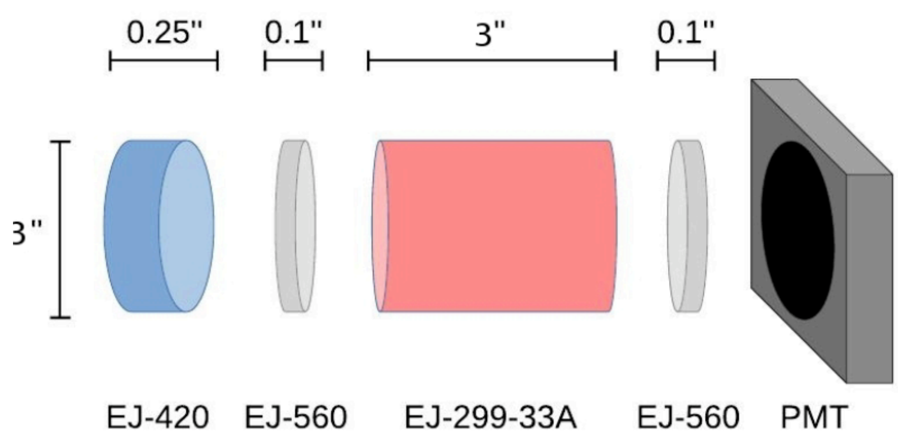
Corrections:

- By atmospheric pressure,
- By temporal fluctuations of incoming cosmic rays (by existing databases of neutron monitoring worldwide stations e.g., Kiel, Germany,
- By air humidity,
- Biomass

Novel detector assembly

Assembling a cheap and easy to build detector made of two commercial scintillators with complementary detection properties, in order to simultaneously detect and discriminate thermal neutron, fast neutron, gamma radiation. Light output is collected with a single-channel readout.

Detector EJ-299-33A + EJ420
Readout Hamamatsu H6559



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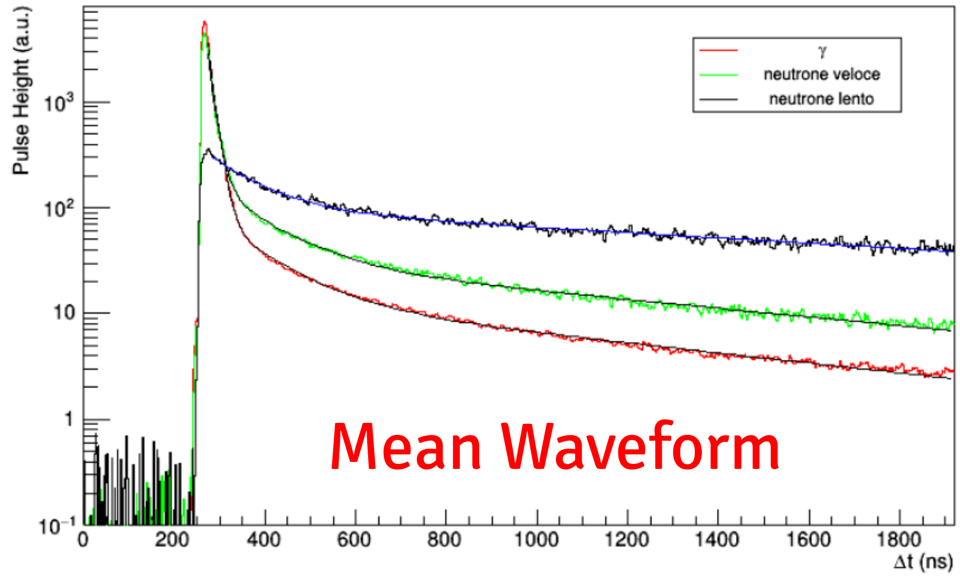
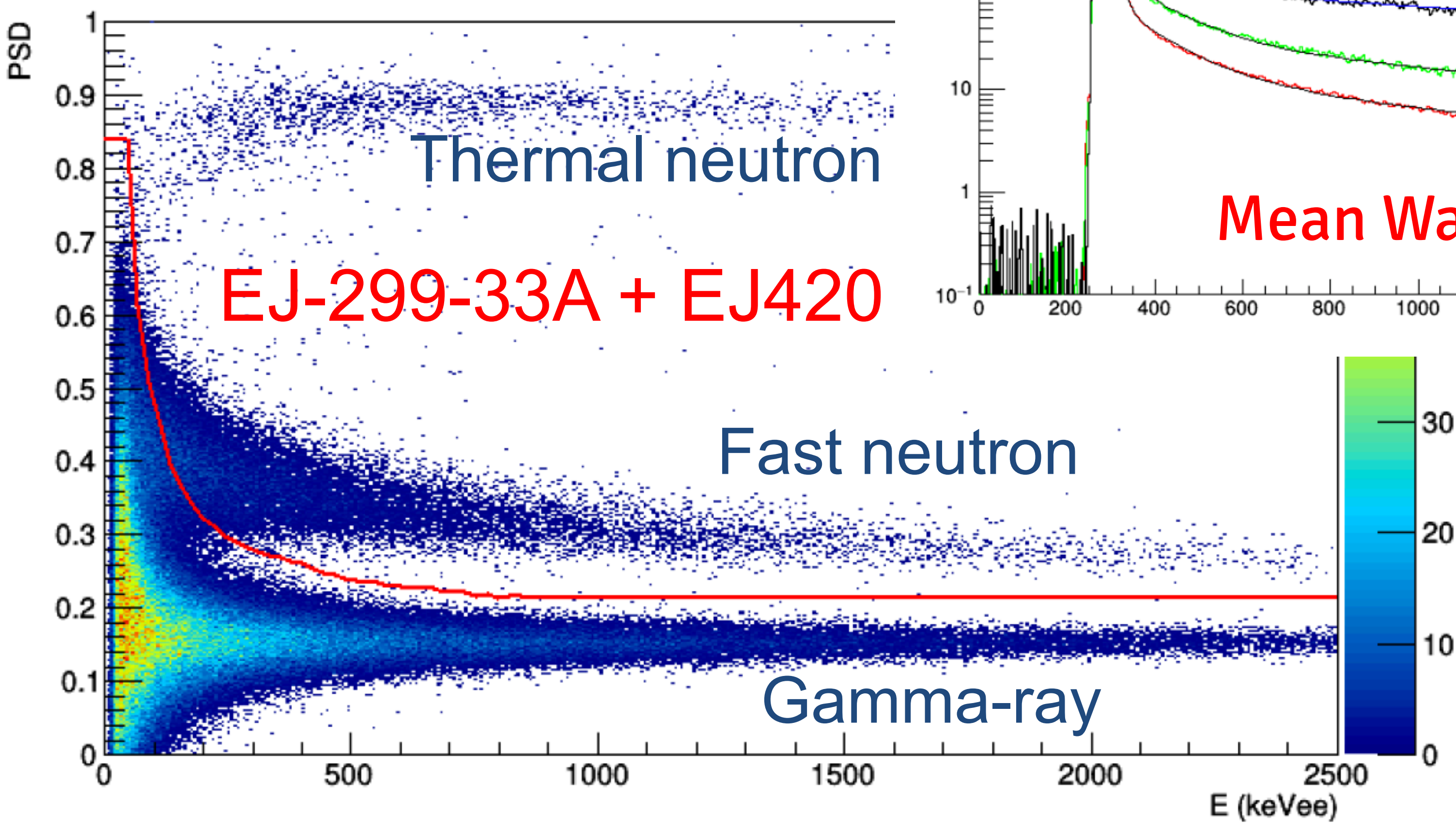
Definition of PSD

$$PSD = \frac{\text{Tail Integral}}{\text{Total Integral}}$$





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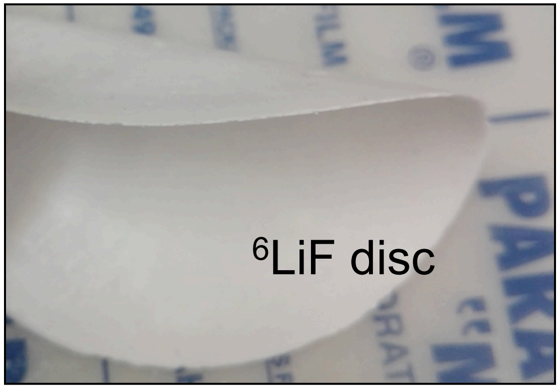
Testing detectors

We tested the detectors in several configuration in order to check any worsening of the performance in the final configuration. Furthermore, we characterized two cheaper and more resistant prototype synthetize at Laboratori Nazionali di Legnaro.



Newly developed flexible thermal neutrons detectors containing ^{6}LiF nano-crystals developed @ LNL

Different configurations:

1. EJ-299-33 (2013) 2”
2. EJ-299-33A (2015) 2”
3. EJ-299-33A + EJ420 2”
4. EJ-299-33A + 6LiF disc
5. PSS10PPO06 2”
6. EJ-299-33A + EJ420 3”

Acquisition Sistem
CAEN Digitizer V1730 500Ms/s 14bit
CAEN HV power supply V6533
CAEN USB Bridge V1718

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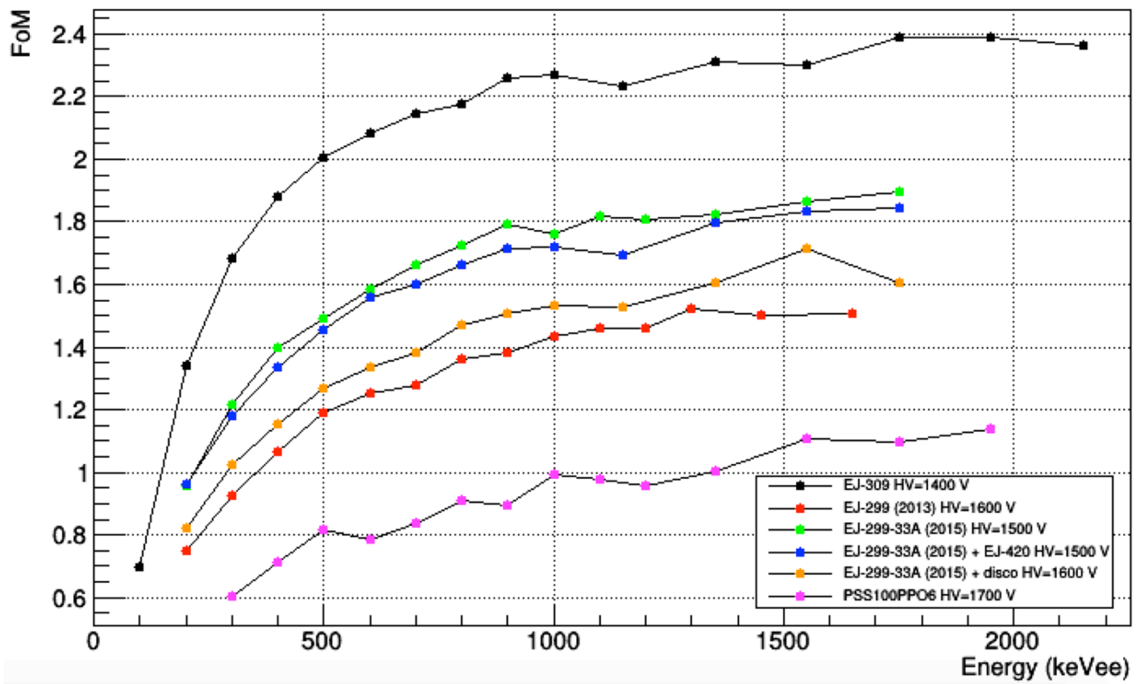
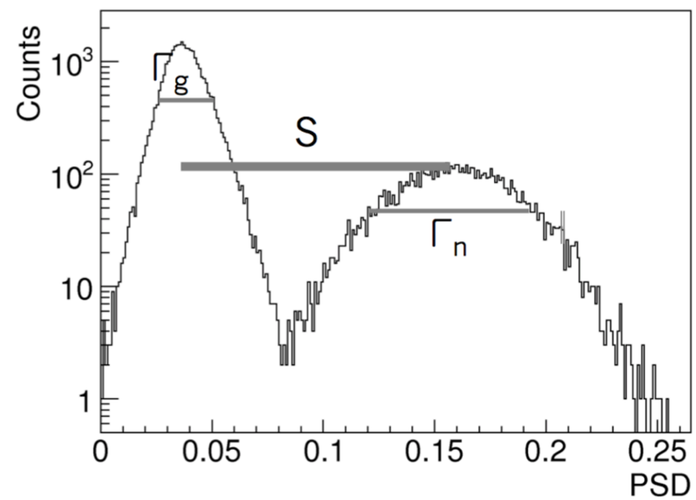
Figure of Merit



$$FoM = S / (\Gamma_n + \Gamma_g)$$



Green: EJ-299-33A (2015)

Blue: EJ-299-33A + EJ420

Worsening of the PSD capability of few percent

Efficiency

	Neutron Counts		Relative efficiency	
Detector 2”	Fast	Thermal	Fast	Thermal
EJ-309 (reference)	40185	-	100	-
EJ-299-33 (2013)	20235	-	50	-
EJ299-33A (2015)	31226	-	78	-
EJ299-33A + EJ420	26995	814	67	100
EJ299-33A + ^{6}LiF disc	20149	855	50	105
PSS100PPO6	15814	-	39	-

Efficiency for thermal neutron of ^{6}LiF disk is 100% compared to commercial EJ420

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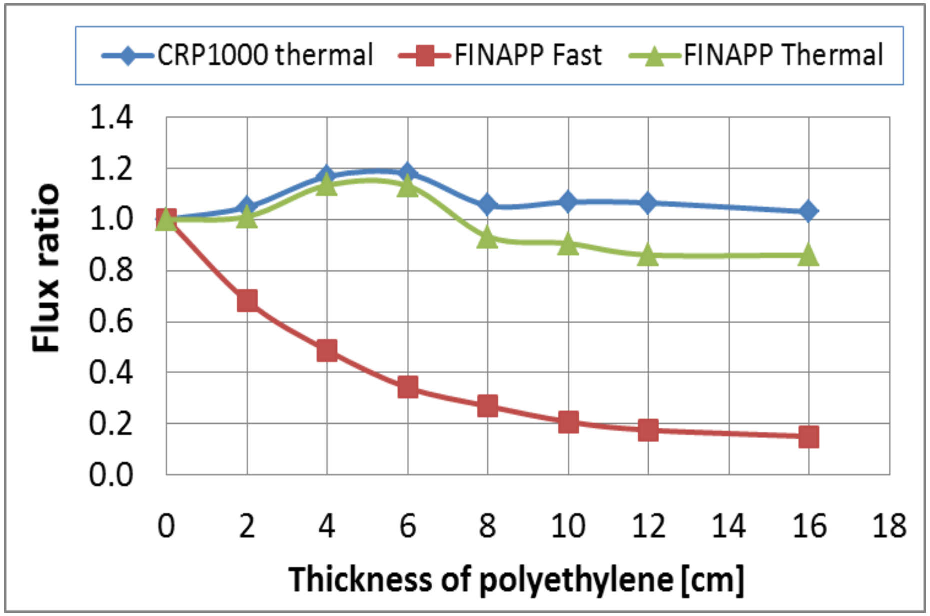
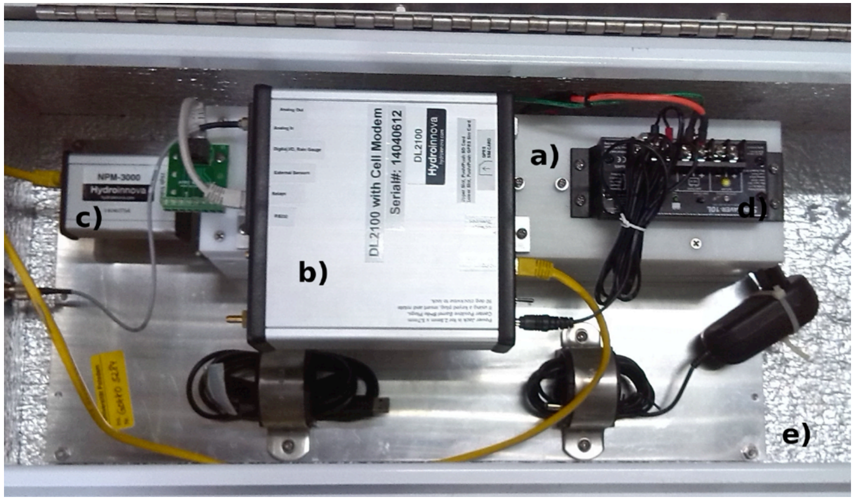
Comparison 3" and CRS1000 probe

Thickness Poly (cm)	^{3}He tube	Detector 3" Fast	Thermal	Eff (%)
0	10753	19563	2225	20.7
2	11278	13313	2250	20.0
4	12555	9535	2523	20.1
6	12674	6693	2517	19.9
8	11337	5282	2075	18.3
10	11479	4090	2016	17.6
12	11448	3452	1916	16.7
14	11070	2964	1914	17.3

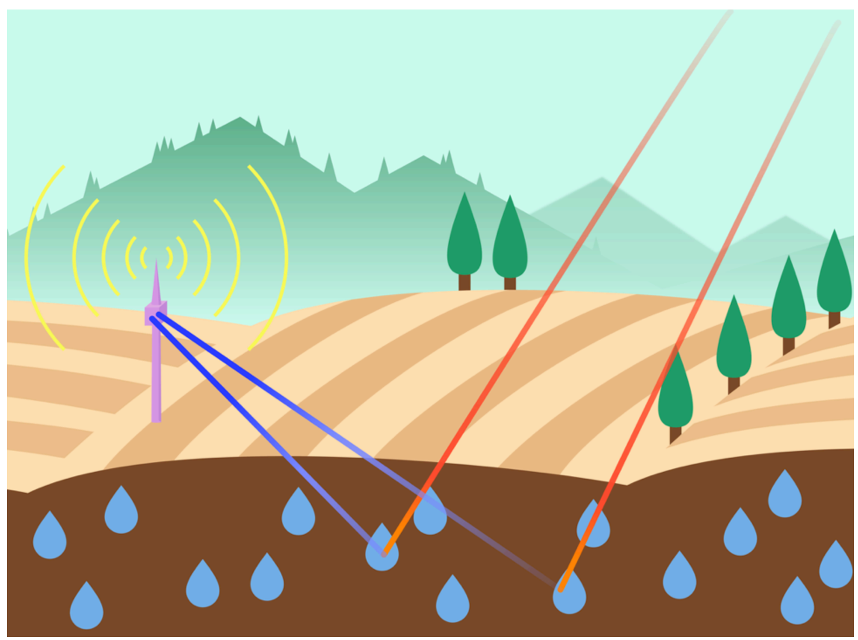




Thanks to flexible thermal neutron detector, it is possible to wrap the plastic detector increasing the efficiency up to 70%

From the lab to the field
Finapp Spin-off

Finapp



Start CUP VENETO

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SEEDS & CHIPS
THE GLOBAL FOOD INNOVATION SUMMIT
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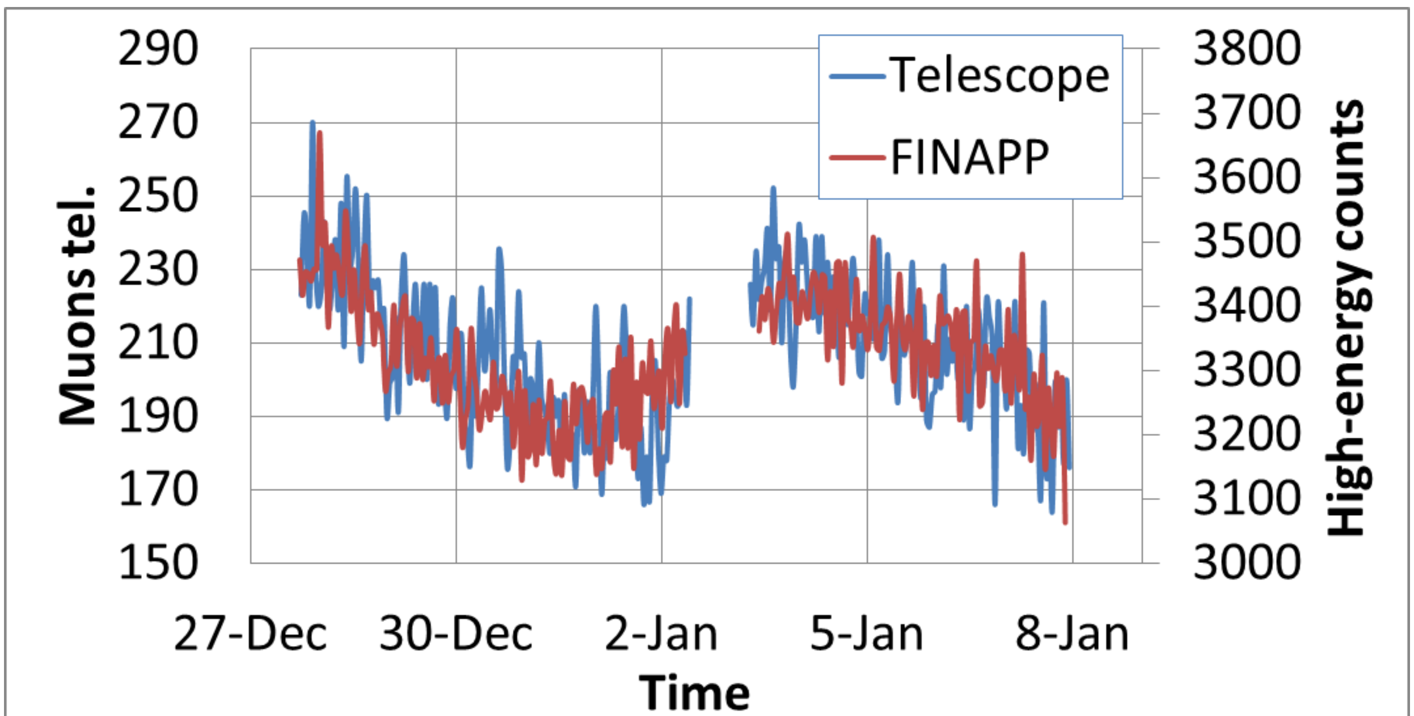
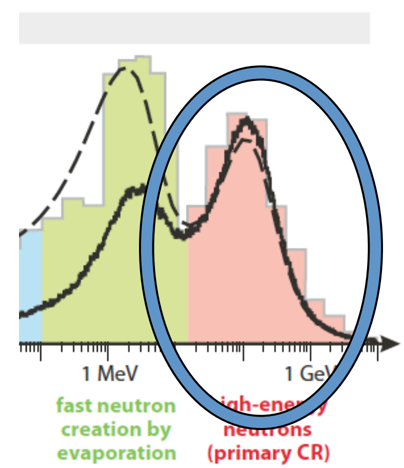
Finapp detector Vs Muon Telescope

Fifteen days measurement in Padova

Comparison between Muons as detected by a Telescope and the high-energy particles (>4MeV) detected by the FINAPP probe shows remarkable agreement. This signal is representative of local conditions





Finapp detector Vs CRS1000 probe

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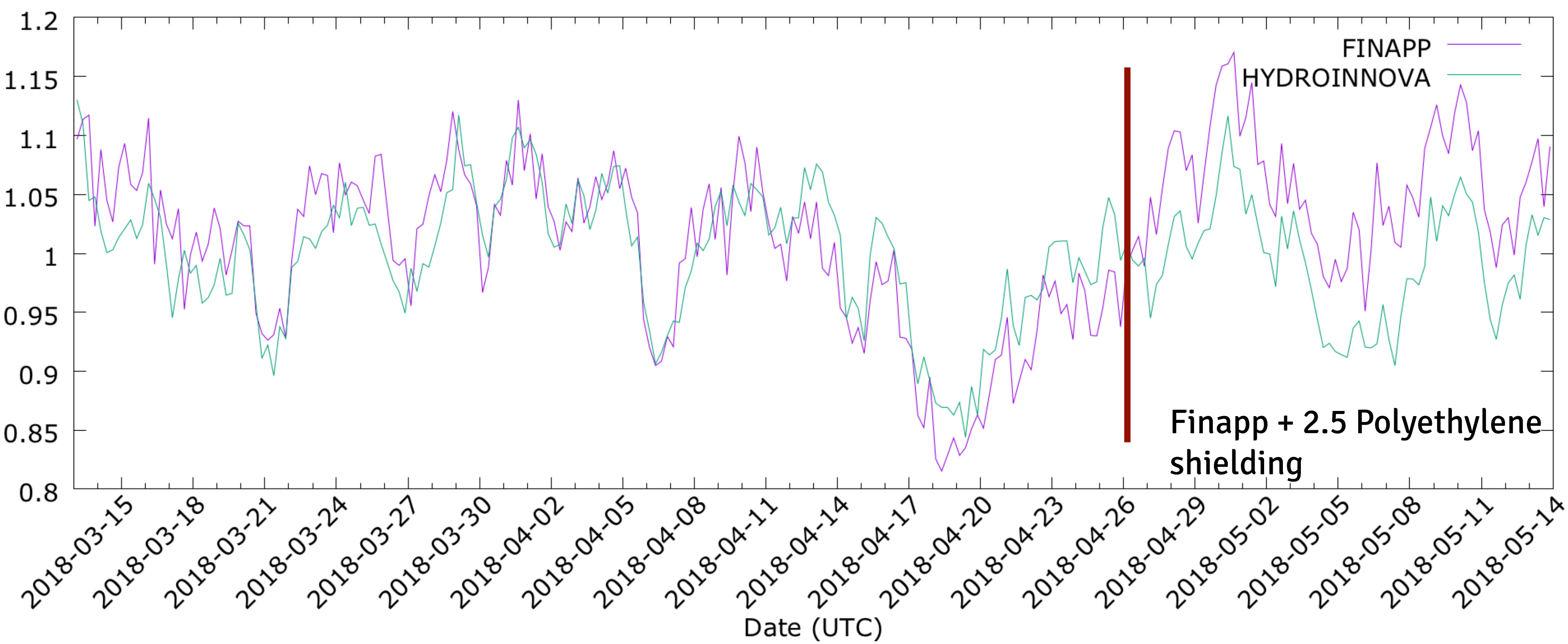
Two months measurement in Potsdam laboratory

Comparison between thermal neutron from Finapp detector and thermal neutron from CRS1000 shows remarkable agreement. On 26th of April, 2.5 cm of Polyethylene was added to Finapp detector to increase efficiency.



Finapp detector vs astmosferic Pressure

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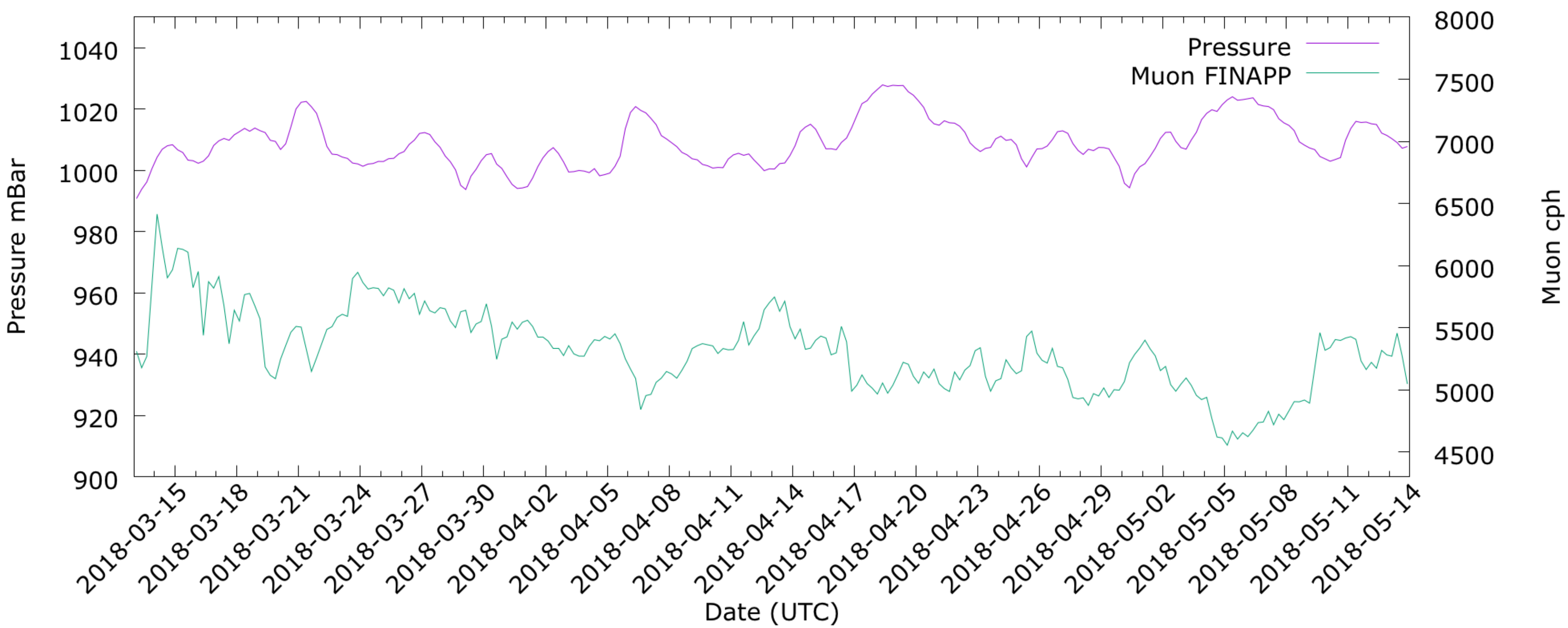
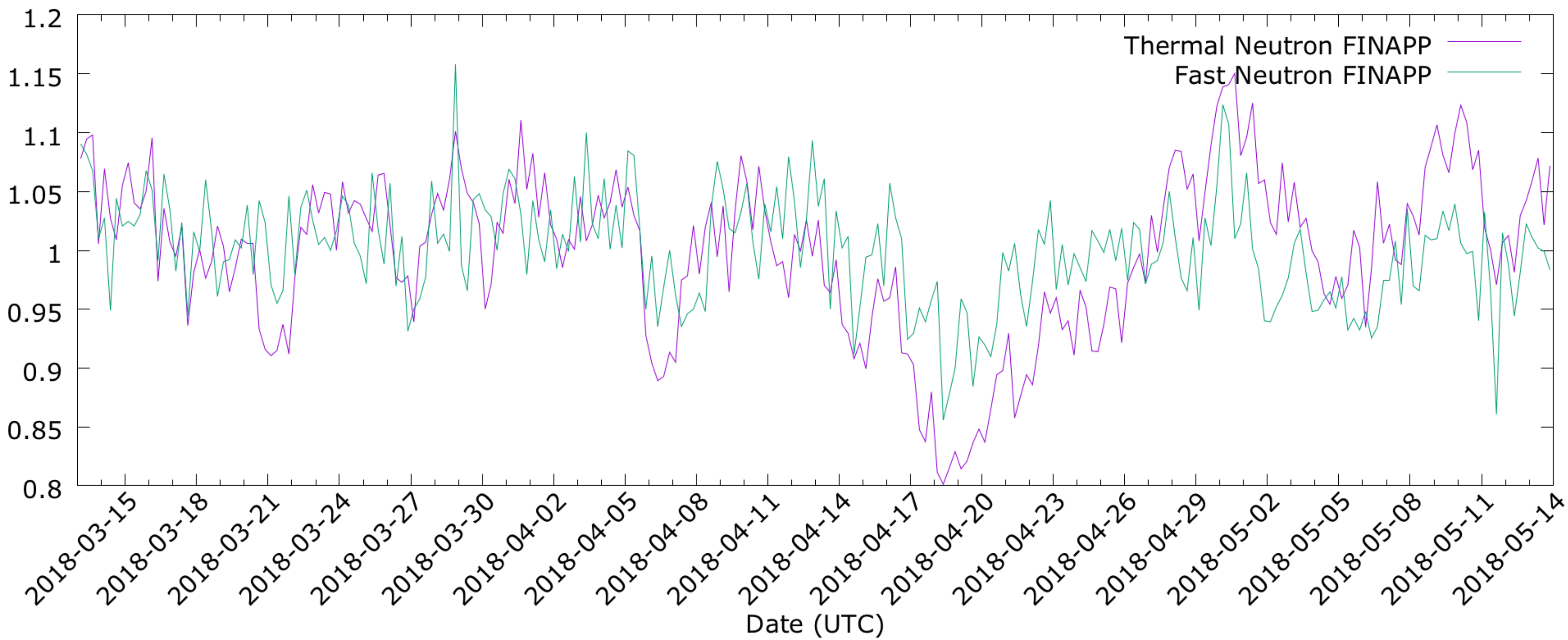
Two months measurement in Potsdam laboratory

Comparison between Muons as detected by a Finapp and atmospheric pressure. Muon flux is anti-correlated with pressure as we expected.



Two months measurement in Potsdam laboratory

Comparison between Thermal and Fast neutron detected by FINAPP probe. Discrimination between thermal vs. fast could show additional information on different hydrogen pools (biomass, snow) at different spatial and temporal scales.



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Conclusion

CRS1000

- uses high-energy neutrons data obtained from neutron data base http://www.nmdb.eu/
- No efficiency for fast neutron and gamma-ray
- Very expensive

Finapp

- Muons could be used for incoming corrections;
- Discrimination between thermal vs. fast (and gamma) could show additional information on different hydrogen pools (biomass, snow) at different spatial and temporal scales
- Price reduction by a factor four