Neutron monitoring

Adam Anderson
Julien Billard
Enectali Figueroa-Feliciano
Joseph Formaggio
Alexander Leder
Lucy Zhang

Neutron Benchmarking Meeting 30 May 2013

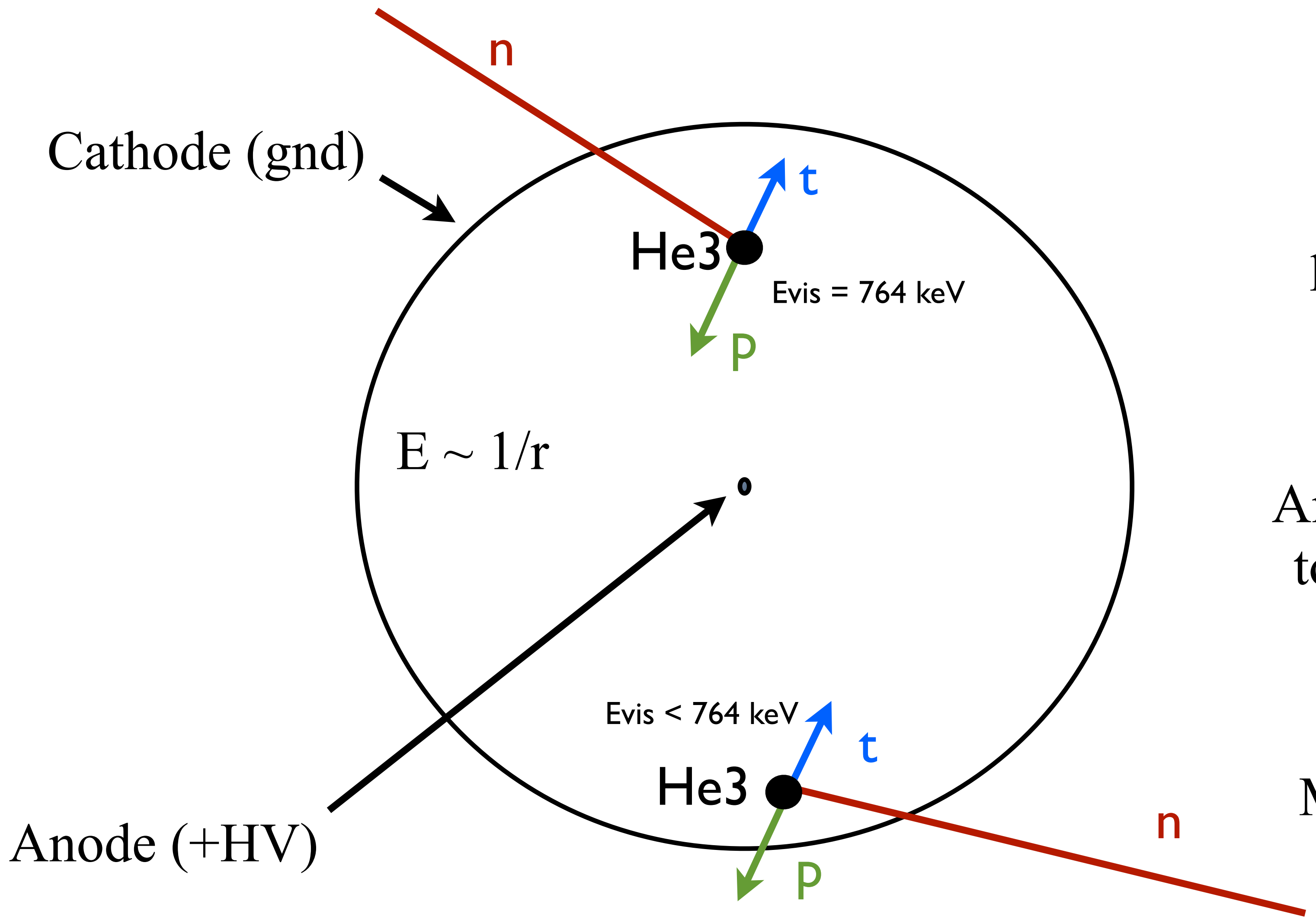
Neutron monitoring

Use of He3 Neutron Capture Detector (NCD) based on the following process:

$$n +^{3} He \rightarrow p + t \quad (Q = 764 \text{ keV})$$

proton: 573 keV
triton: 191 keV

- **Cylinder shape:** 200 cm long, 5.08 cm diameter => active volume ~ 4000 cm3
- **Gaseous TPC:** 85% 3He + 15% CF4 @ 2.53 bar



p and t release most of their energy by ionization

↓

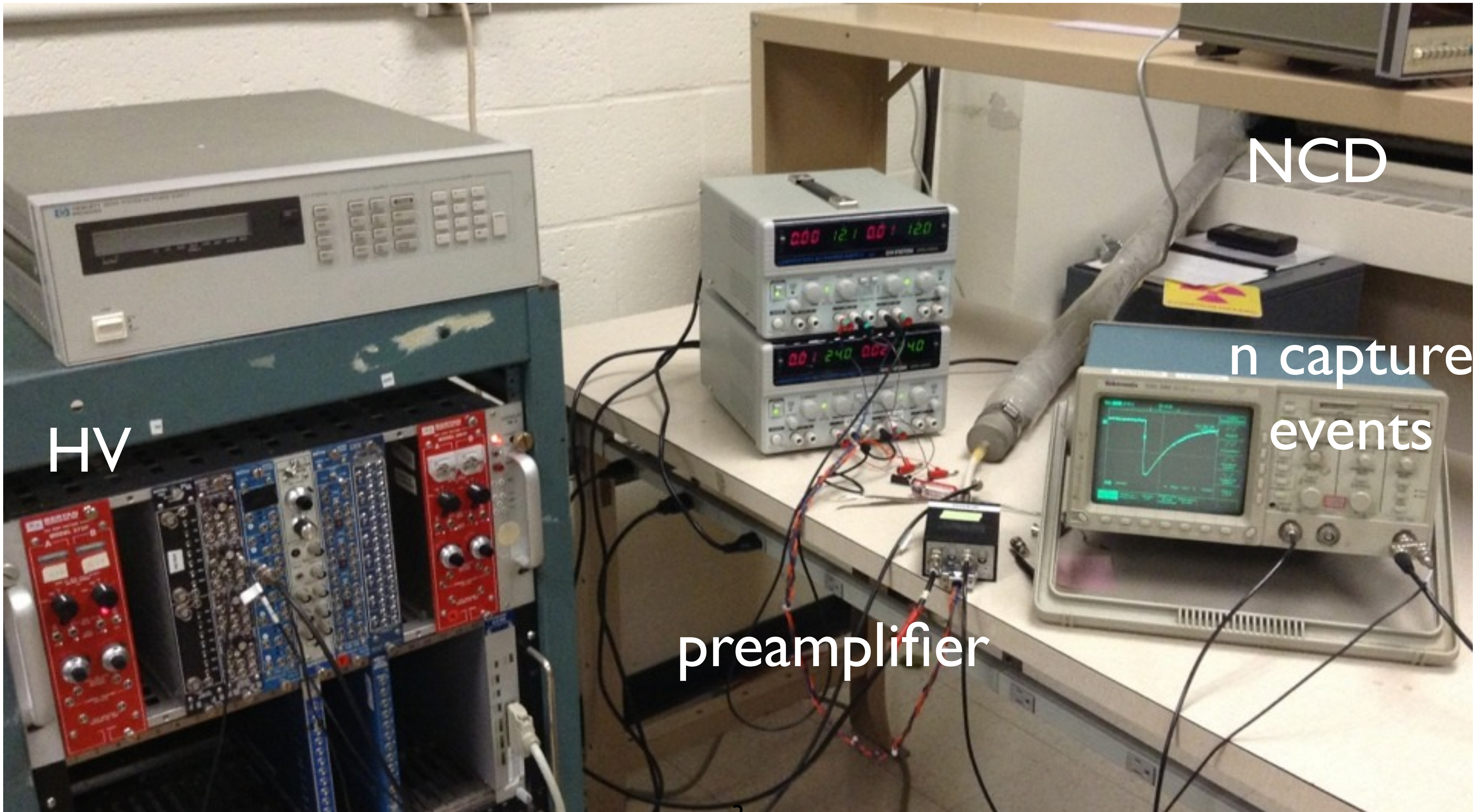
Amplification of the signal due to avalanche process near the anode wire

↓

Measurement of the collected charges proportional to the event energy

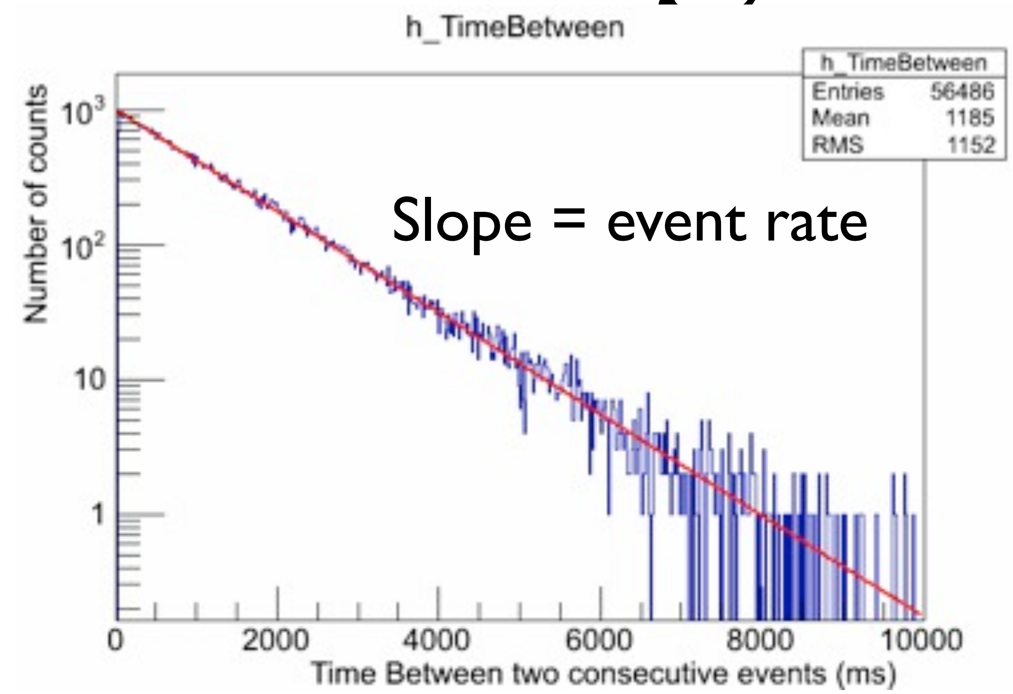
Neutron monitoring

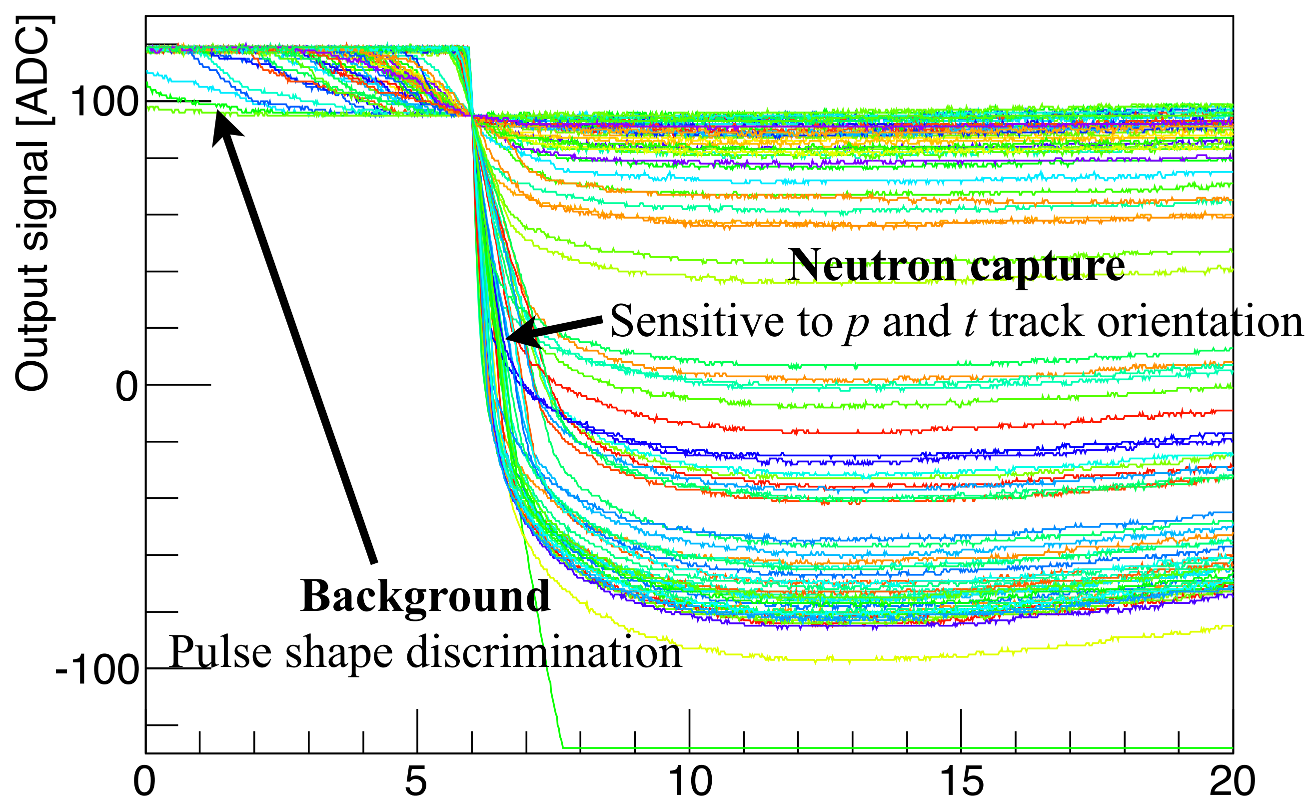
Detector



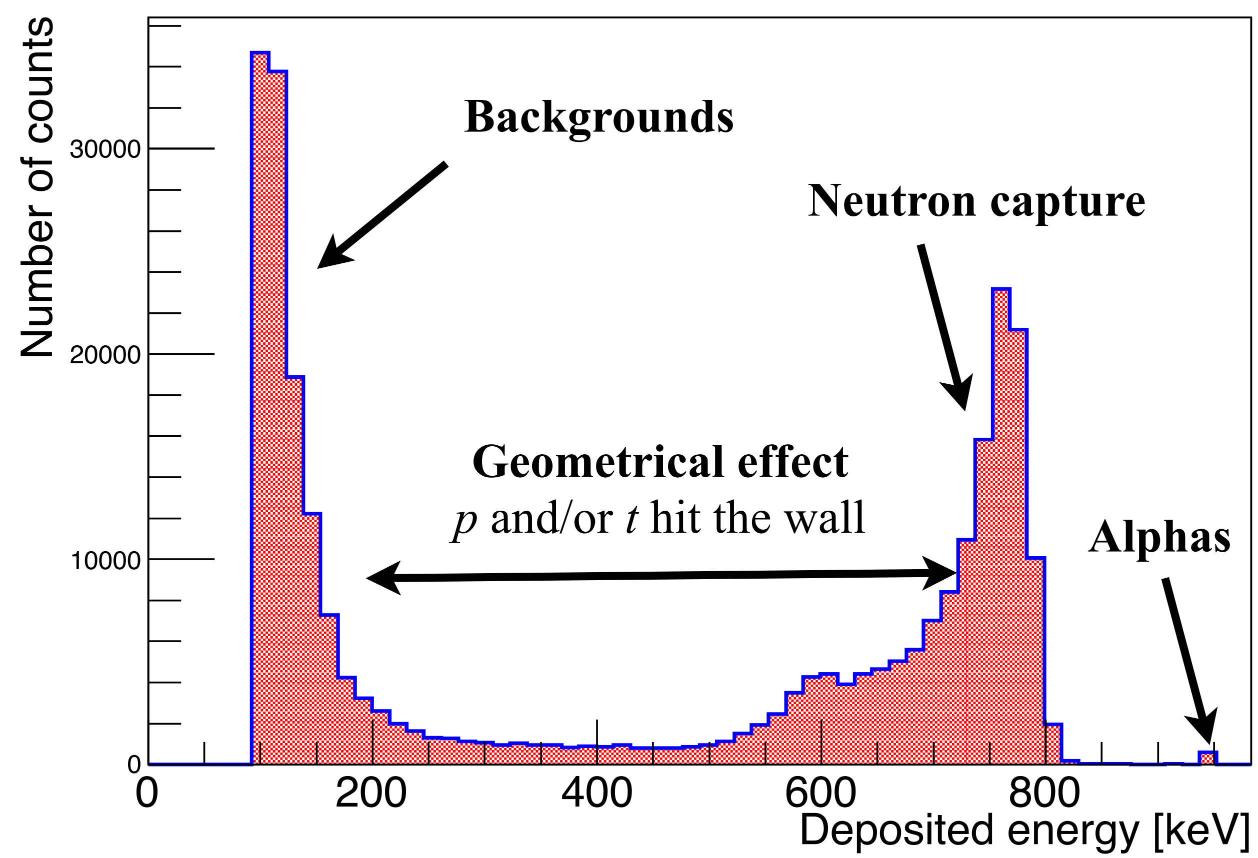
Neutron monitoring

- **Charge readout:** charge preamplifier Canberra (rise time: 75 ns and fall time: 50 us)
- **ADC 8 bits:** NI USB-5132 @ 50 MHz
- **DAQ software:** Labview
- **Optimal HV:** 1.95 kV
- **Energy resolution @ 764 keV**: 3.3%



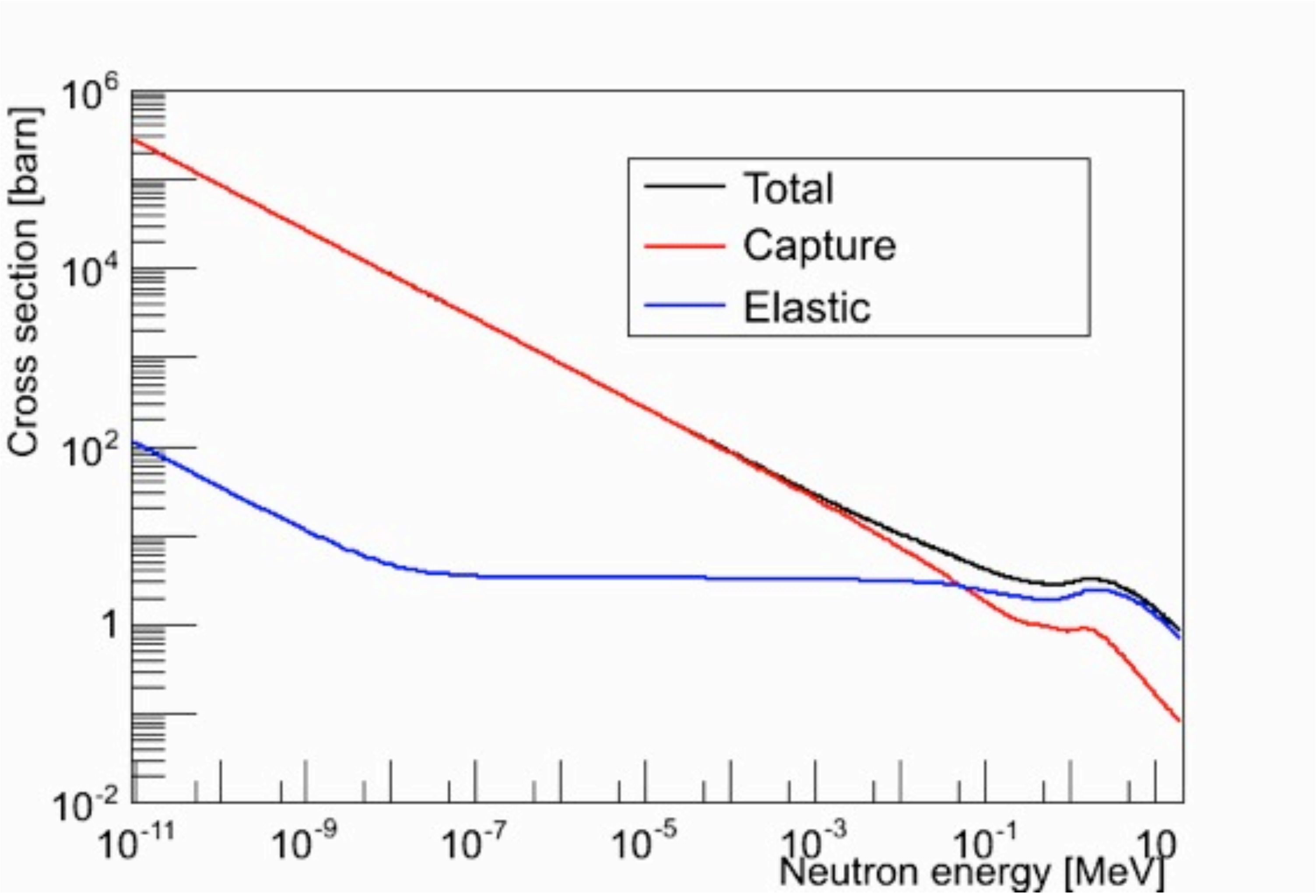


color corresponds to density of energy distribution

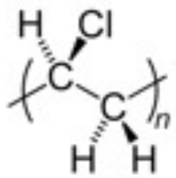


Neutron monitoring

A bonner sphere approach



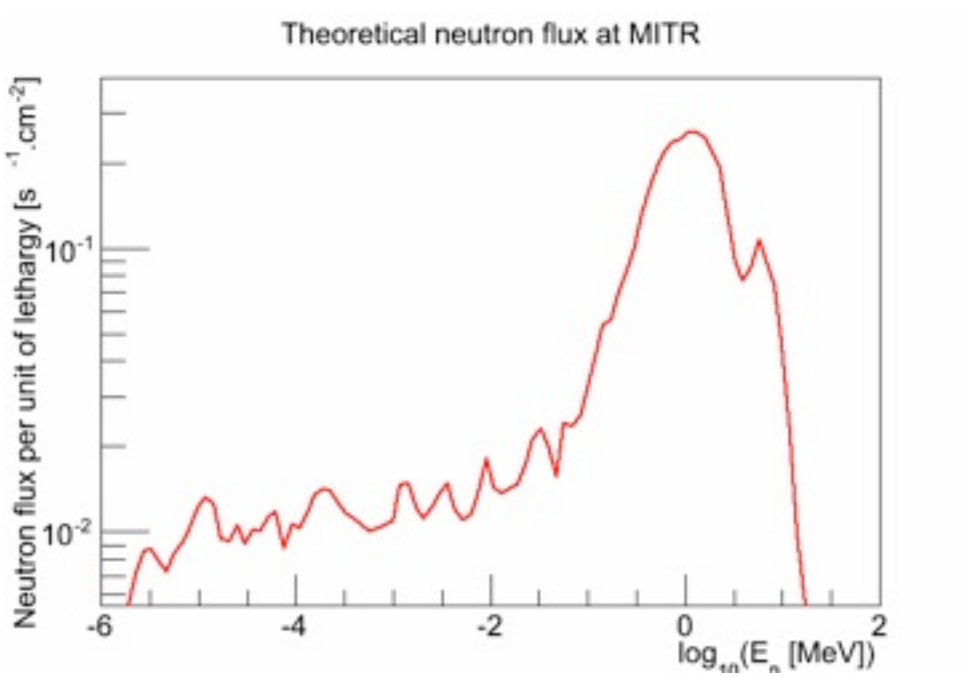
PVC

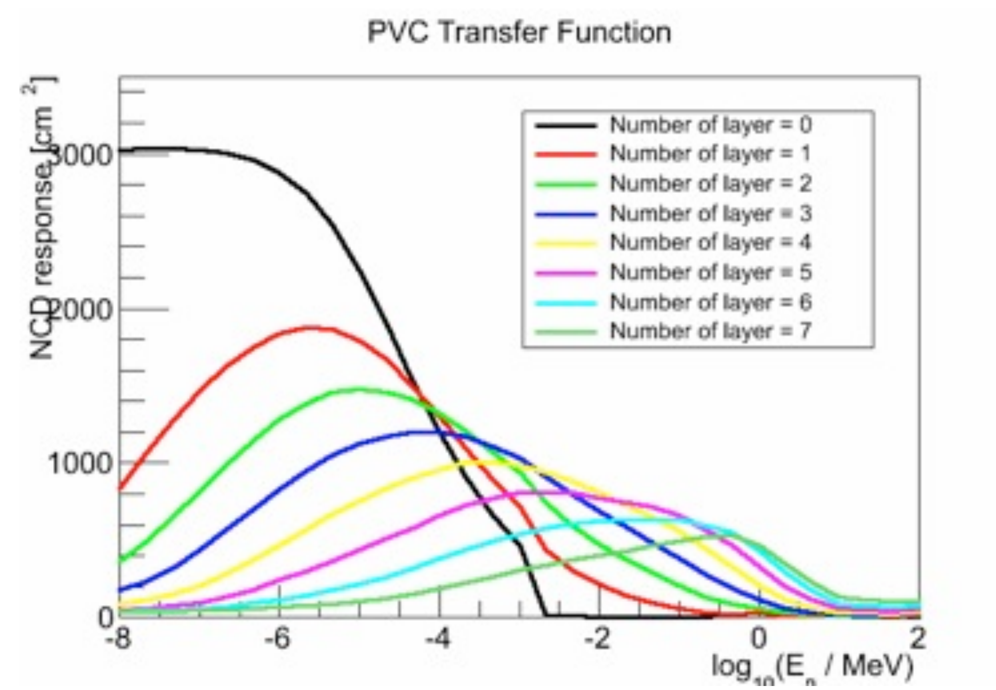


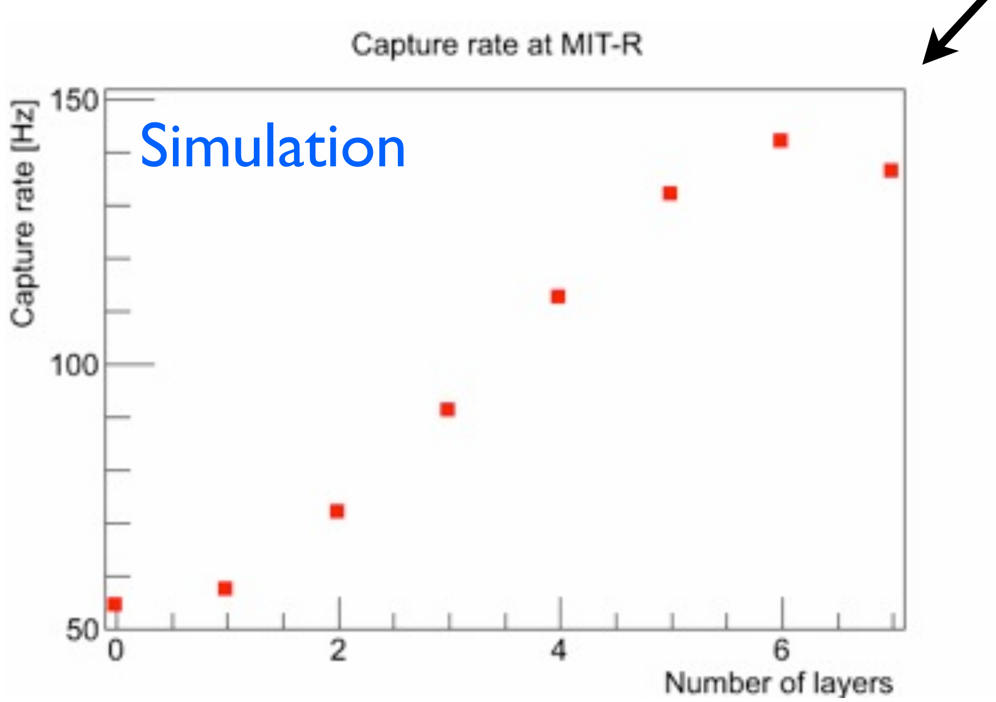
- NCD are mostly sensitive to thermal neutrons (cross section ~ 10^4 barns)
- Use layers of PVC to «slow down» neutrons, due to multiple collisions with hydrogen (mostly), and to be able to measure neutron flux up to MeVs and to recover the energy dependence of the neutron flux!

Neutron monitoring

A bonner sphere approach







Bonner sphere approach in a nutshell:

- Measure the capture rates for different layers
- Compute the transfer functions
- Use a likelihood function to reconstruct the neutron flux

Neutron monitoring

A bonner sphere approach

Definition of the likelihood function:

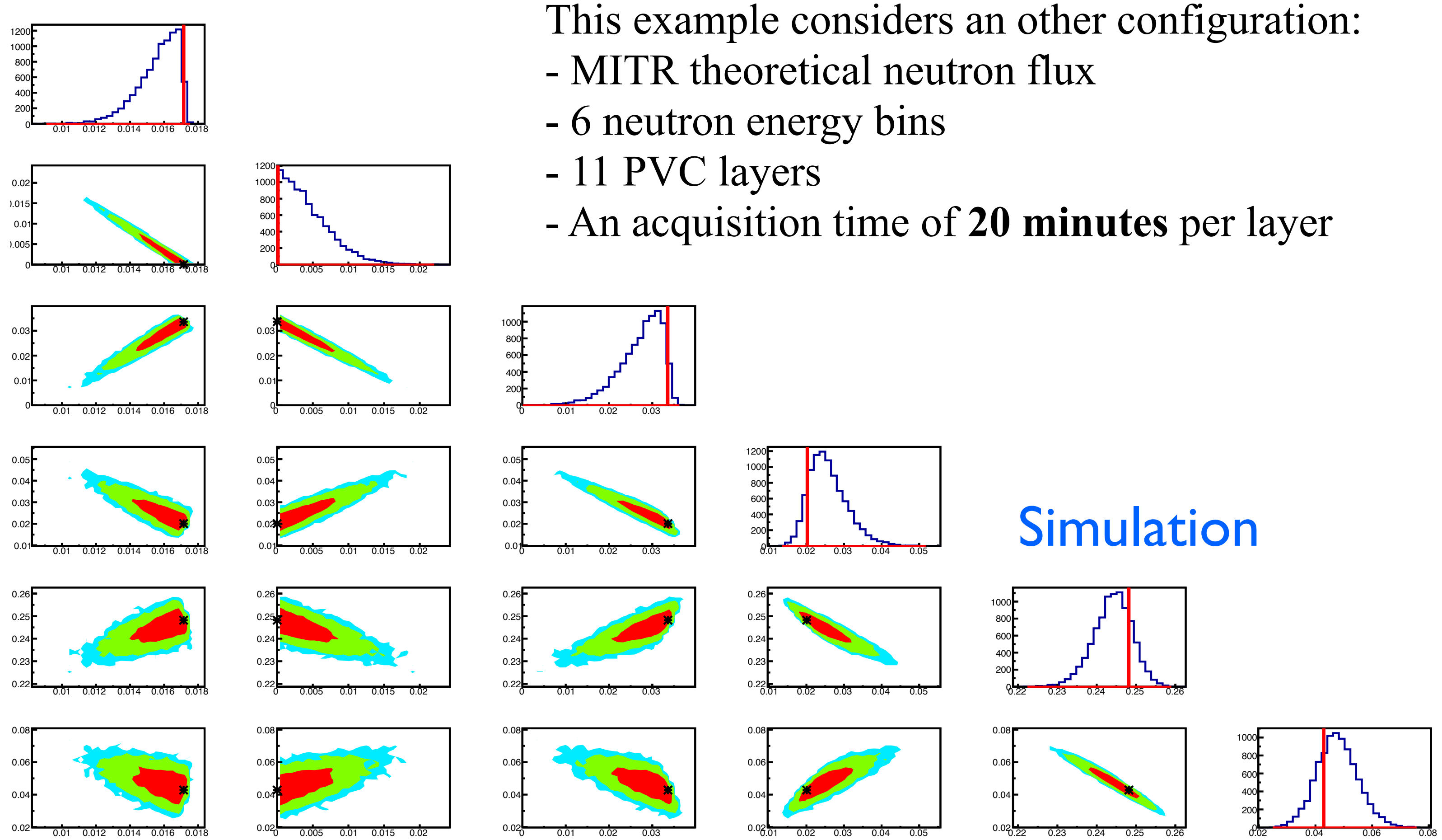
$$\mathscr{L}[\vec{\phi}(\tilde{E})] = \exp\left[-\sum_{j=1}^{N_{\text{layers}}} \frac{\{R_j^{\text{th}}[\vec{\phi}(\tilde{E})] - R_j^{\text{obs}}\}^2}{2\sigma^2_{R_j^{\text{obs}}}}\right]$$

Where the theoretical rates are computed such as:

$$R_j^{\text{th}}[\vec{\phi}(\tilde{E})] = \sum_{i=1}^{N_{\text{bin}}} \int_{\tilde{E}_i}^{\tilde{E}_{i+1}} \phi_i(\tilde{E}) \times T_j(\tilde{E})\, d\tilde{E}$$

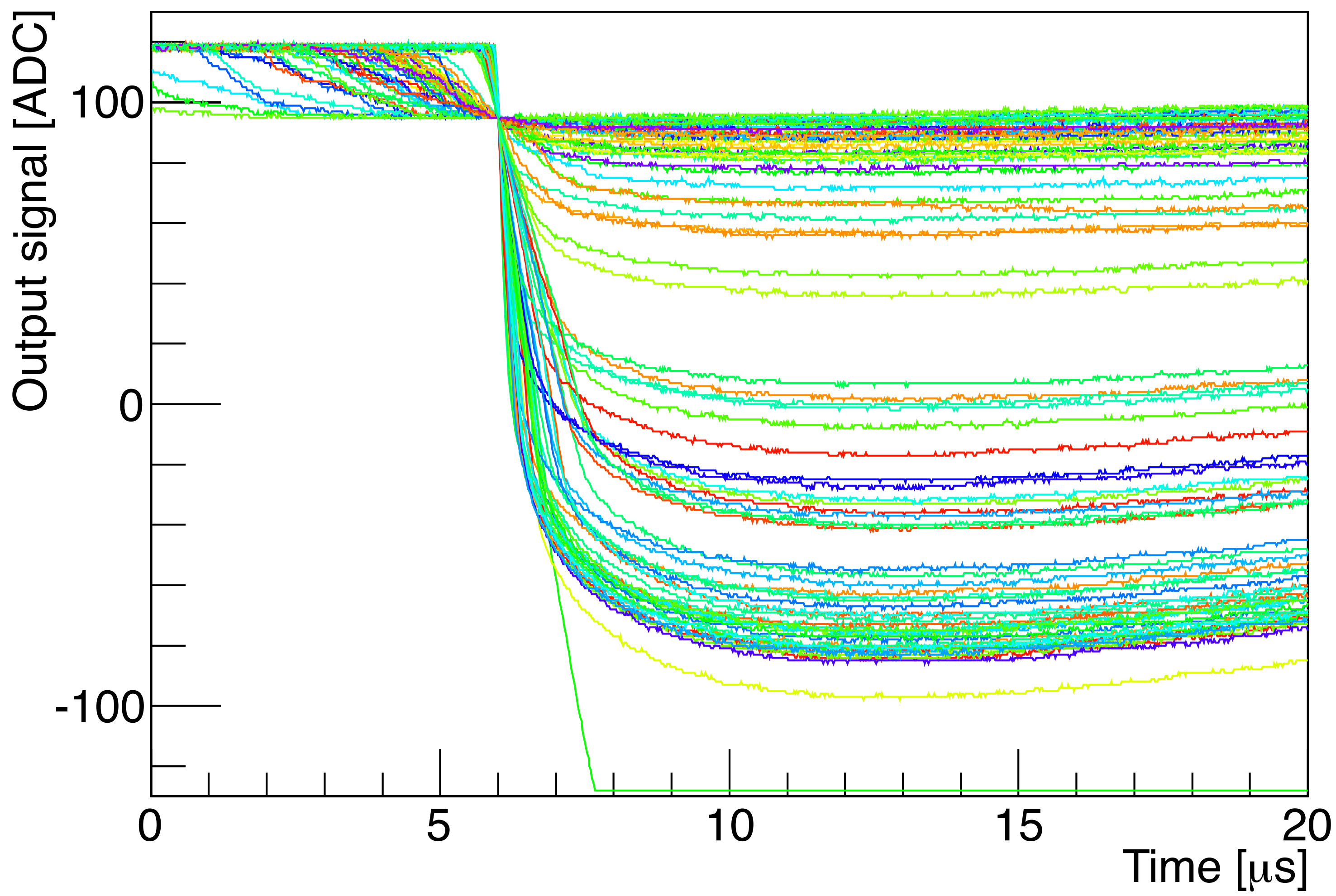
Where $T(E)$ are the transfer functions computed from Geant4

This example considers an other configuration:
- MITR theoretical neutron flux
- 6 neutron energy bins
- 11 PVC layers
- An acquisition time of **20 minutes** per layer



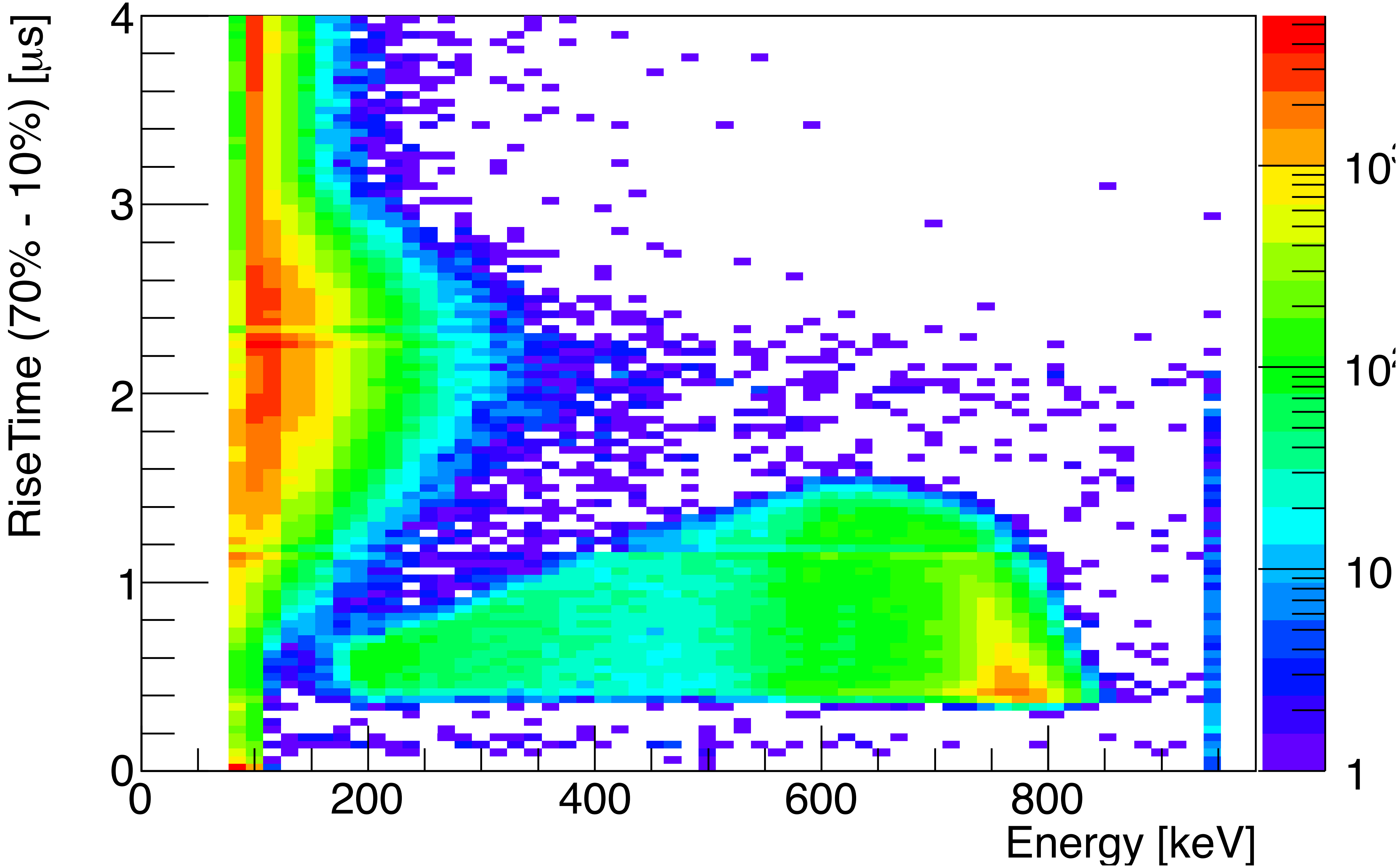
Use of a dedicated MCMC analysis to sample the PDF and propagate systematics in upcoming neutron induced elastic scatterring rates

Pulse shape discrimination

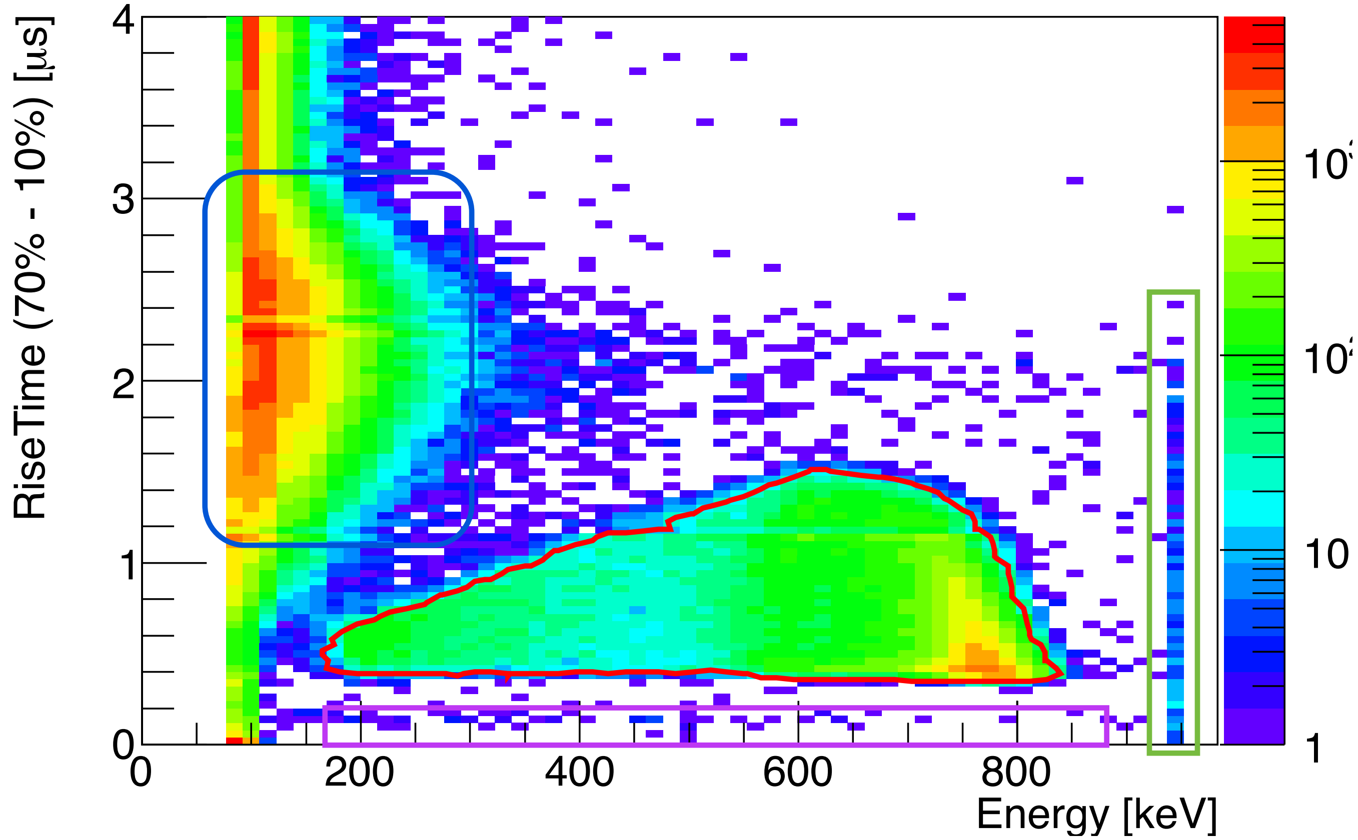


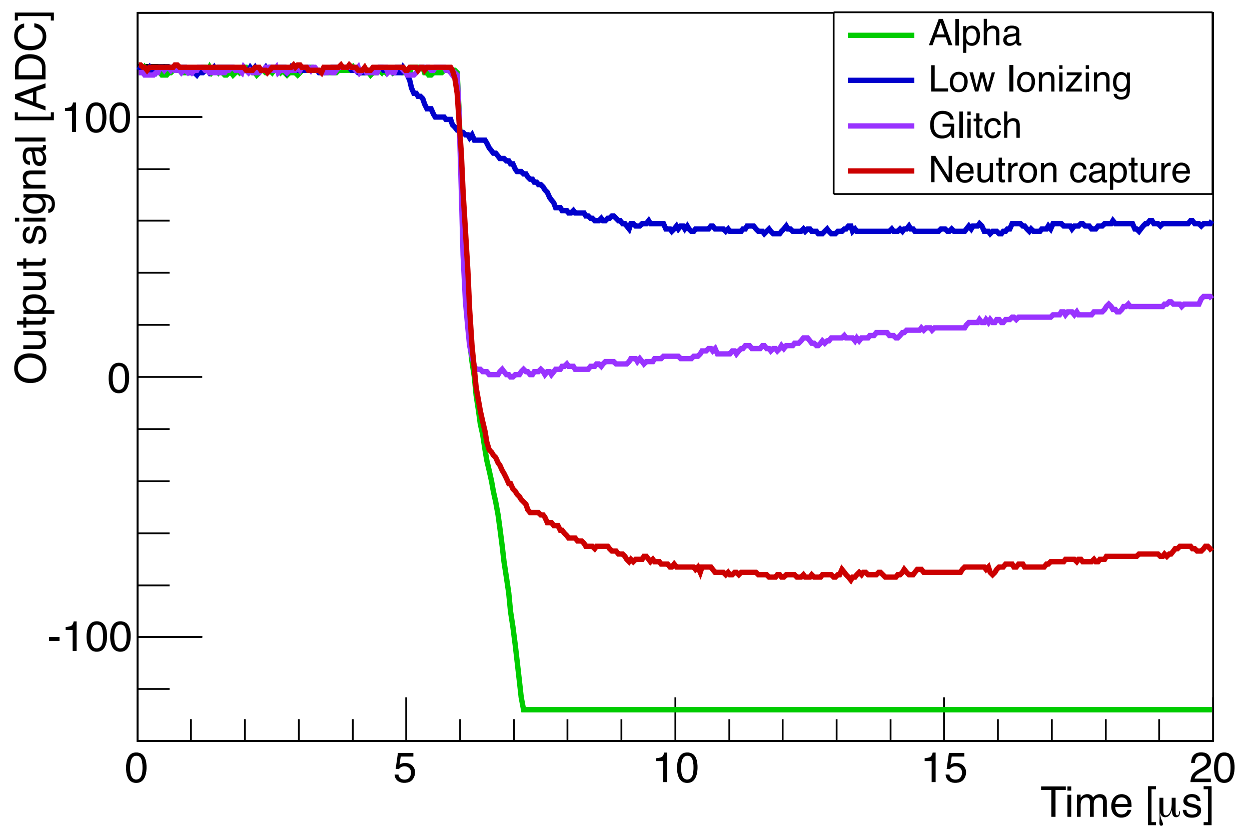
Neutron capture?

Pulse shape discrimination



Pulse shape discrimination





<u>Different type of events</u>

- Alpha event: high energy events

- Glitch event (micro-discharge): Sharp rise and decay time constant characteristic of the CSP

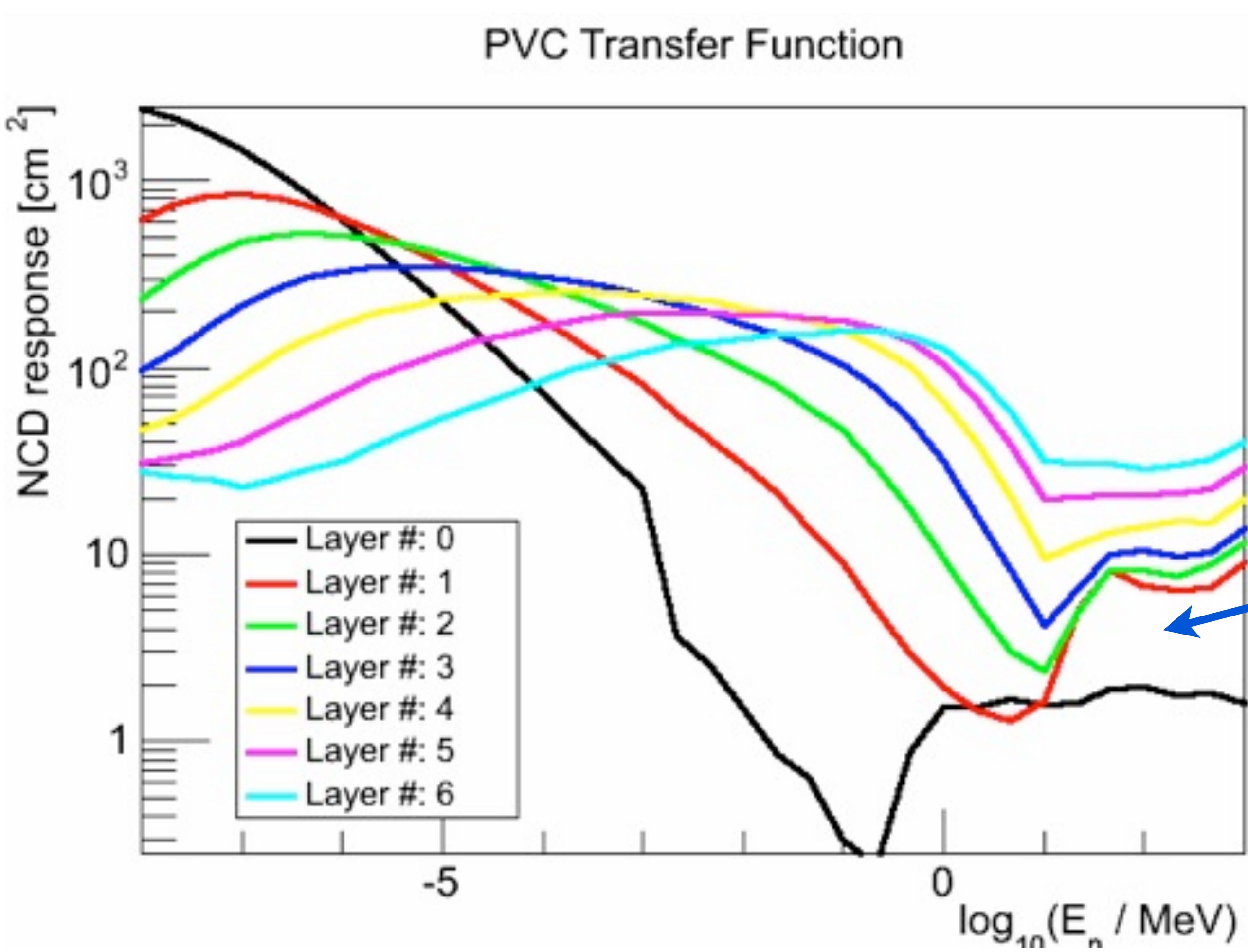
- Low ionizing event: electron recoils, muons, ... low dE/dX

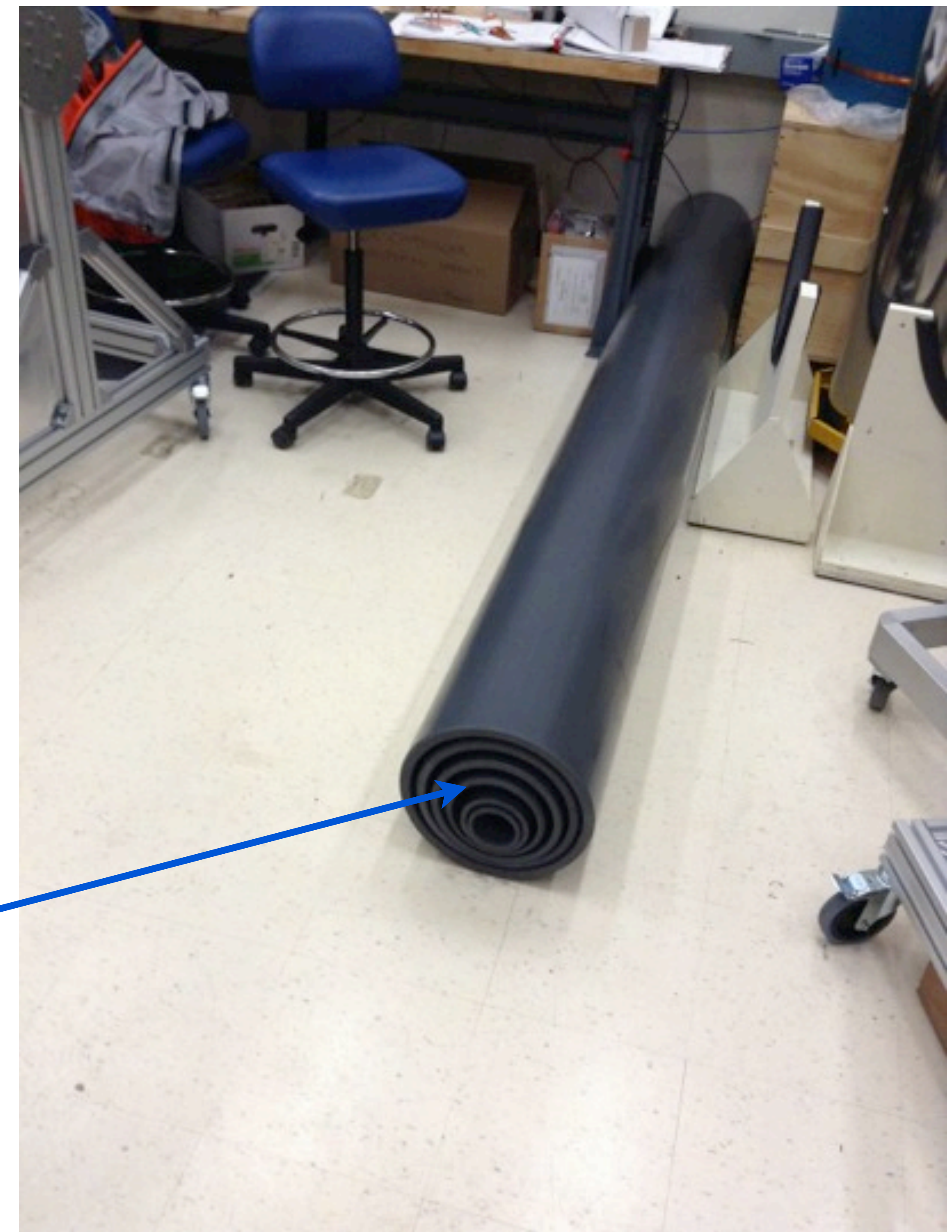
- Neutron capture + nuclear recoils!: large dE/dX, the contour is defined with a 99% efficiency

Data acquisition @ MIT from 03/06 to 03/12

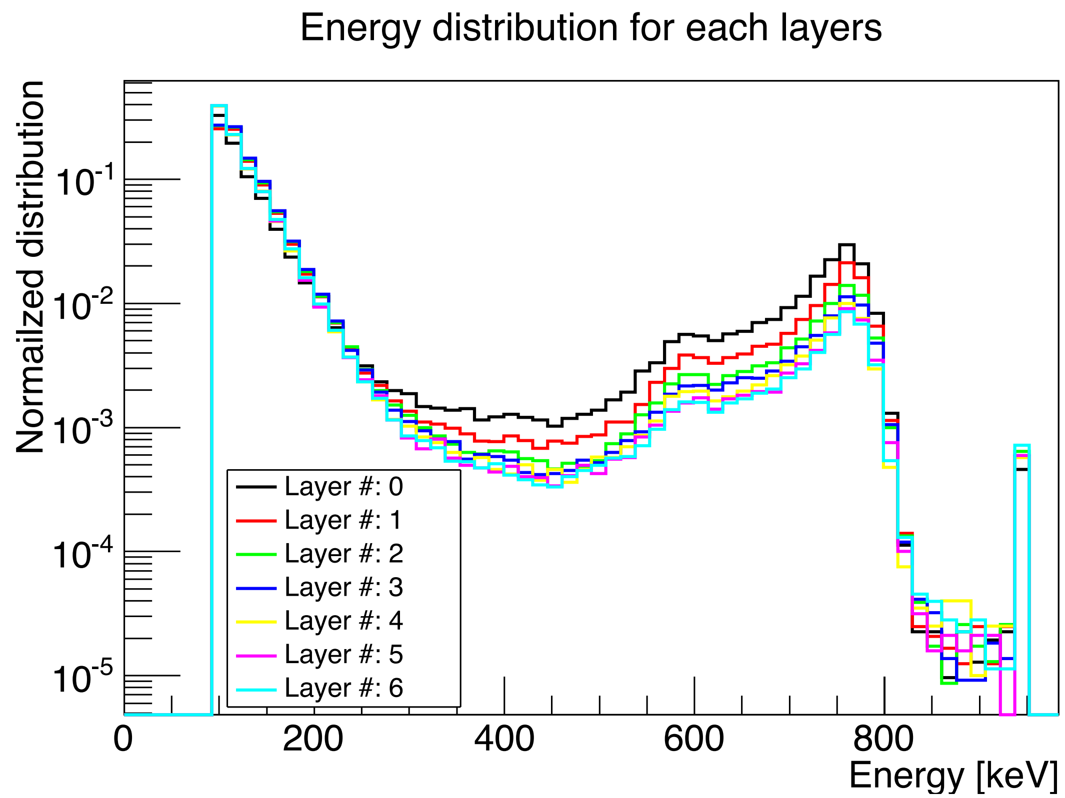
First run @ MIT

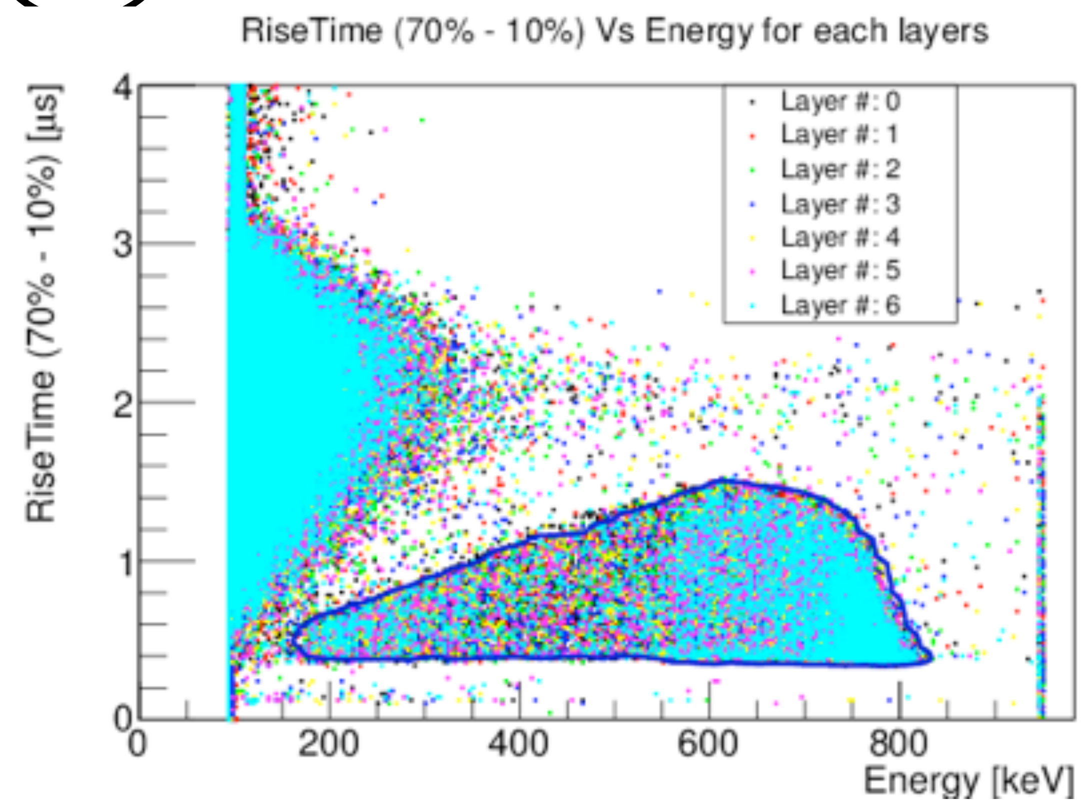
We received our set of pipes on the 03/01!
- Set of 7 PVC pipes
- Only 6 used (the samallest one didn't fit)
- Outer radii in cm: 4.45, 5.72, 8.41, 10.95, 13.65, 16.19

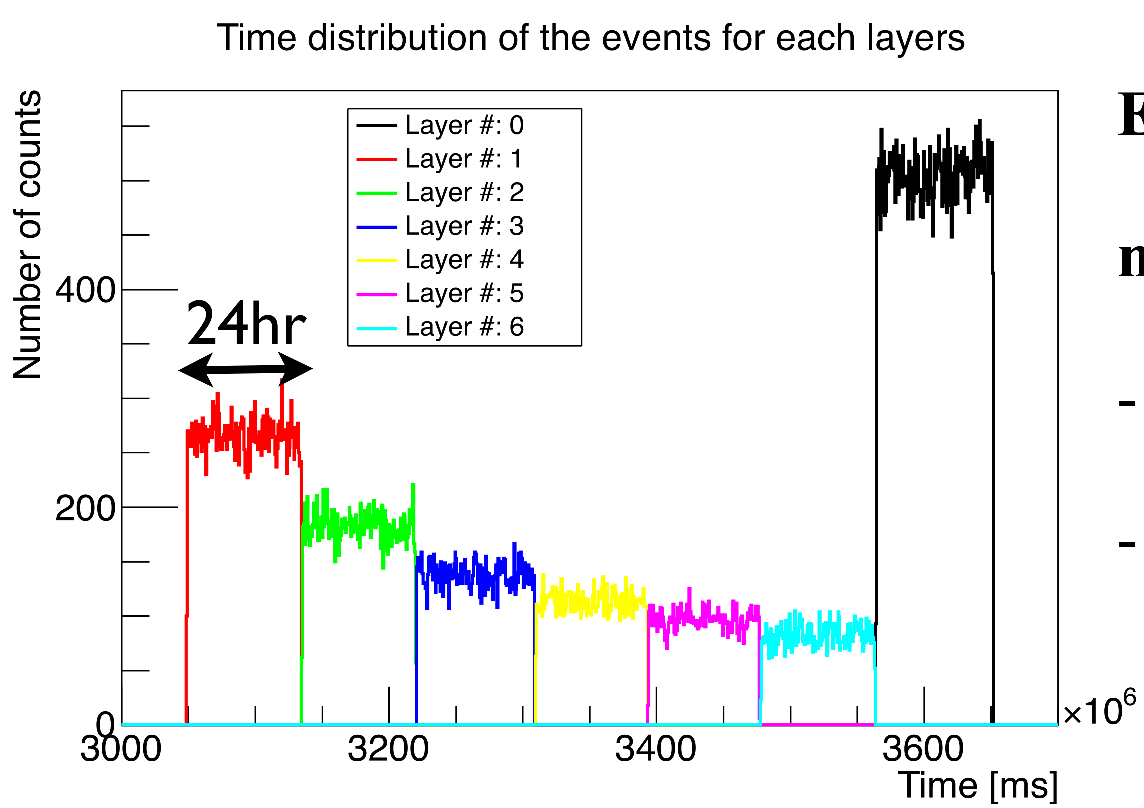




First run @ MIT





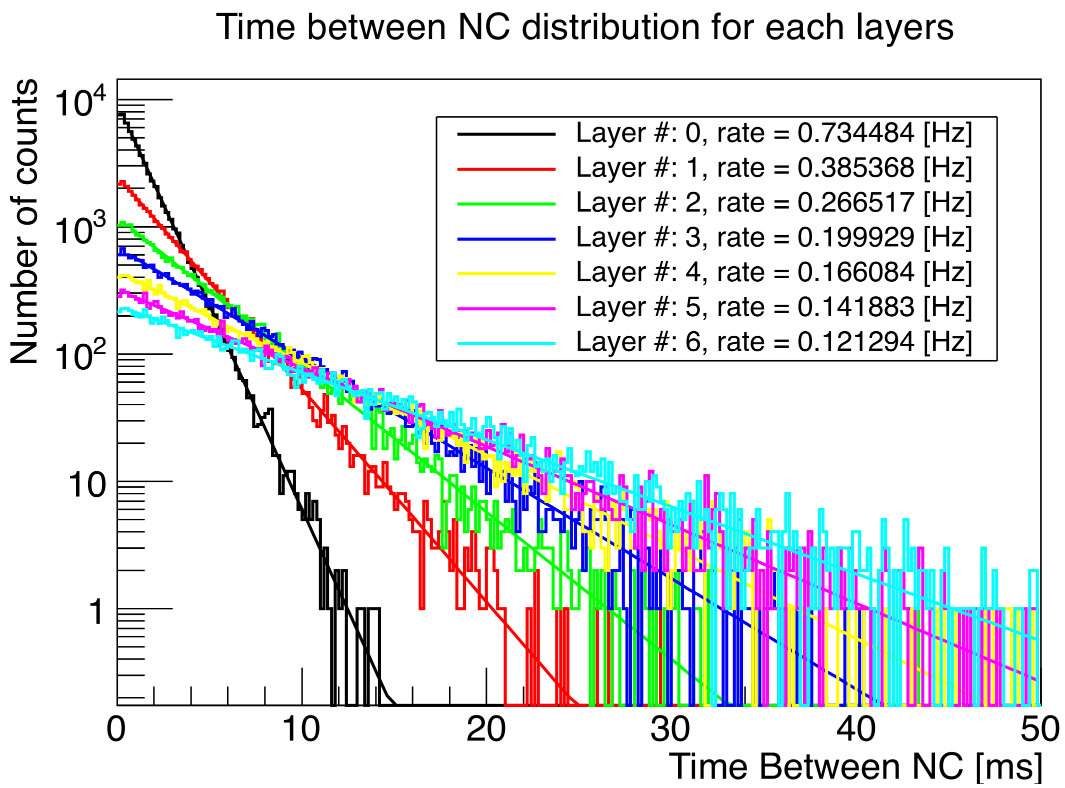


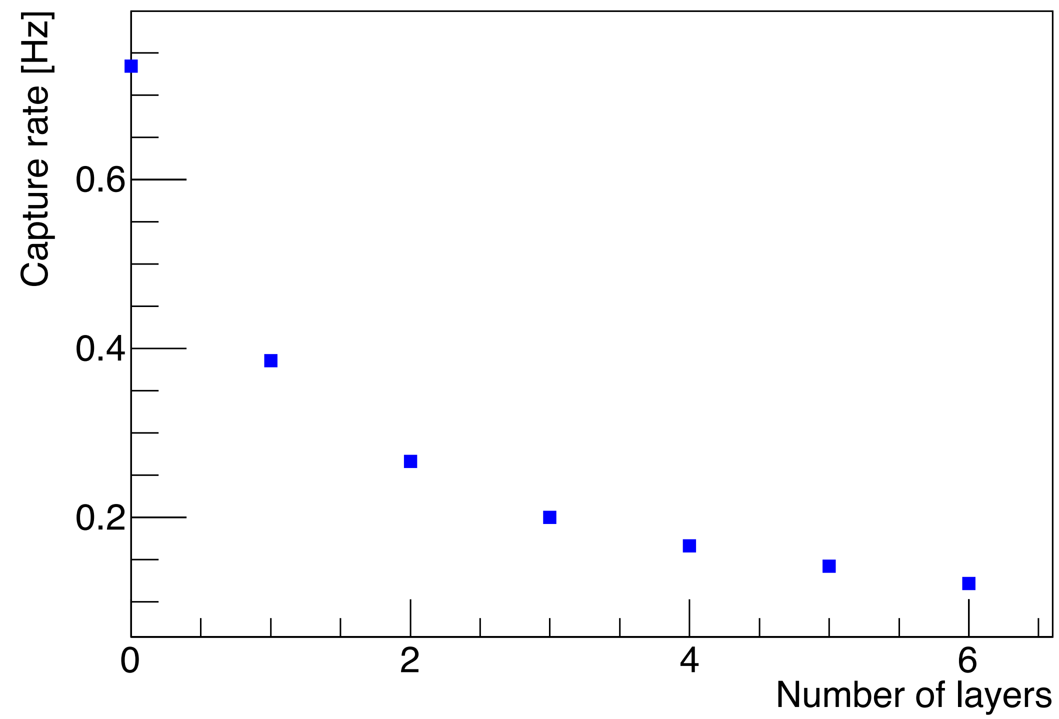
Experiment was very stable during one week of measurements.

- No gain fluctuation

- Neutron capture rate stable

First run @ MIT

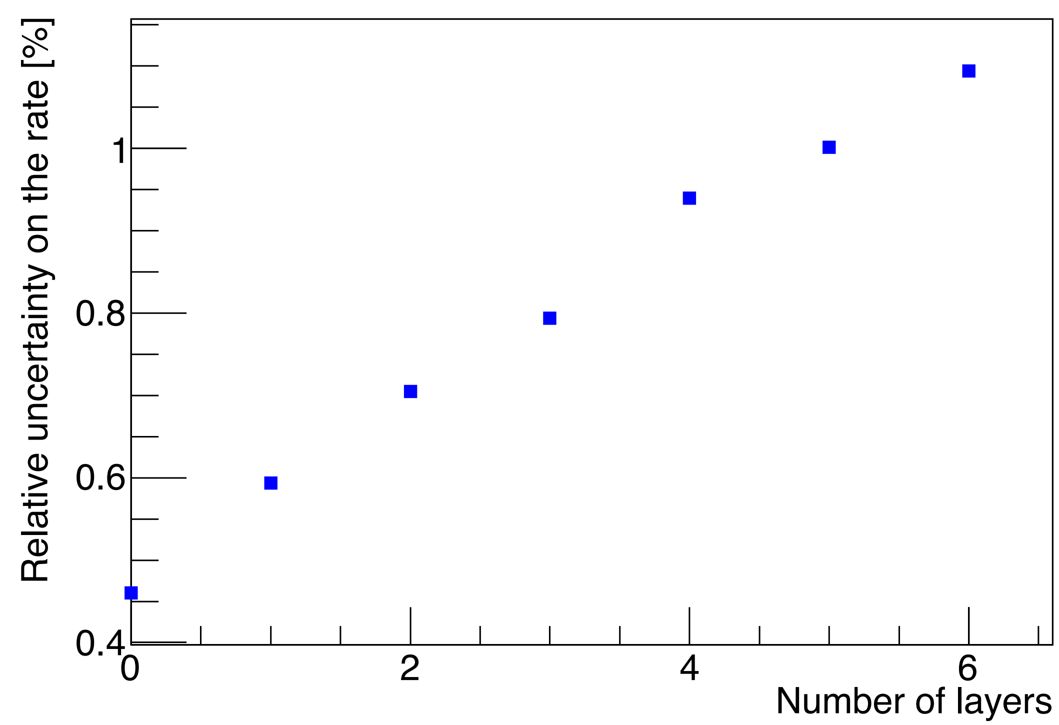




Rates are computed by fitting the TimeBetween NC distributions with an exponential distribution

Capture rates decrease with adding more and more layers, from 0.74 Hz to 0.12 Hz

Relative uncertainties are increasing with the number of layers, from 0.45% to 1.1%

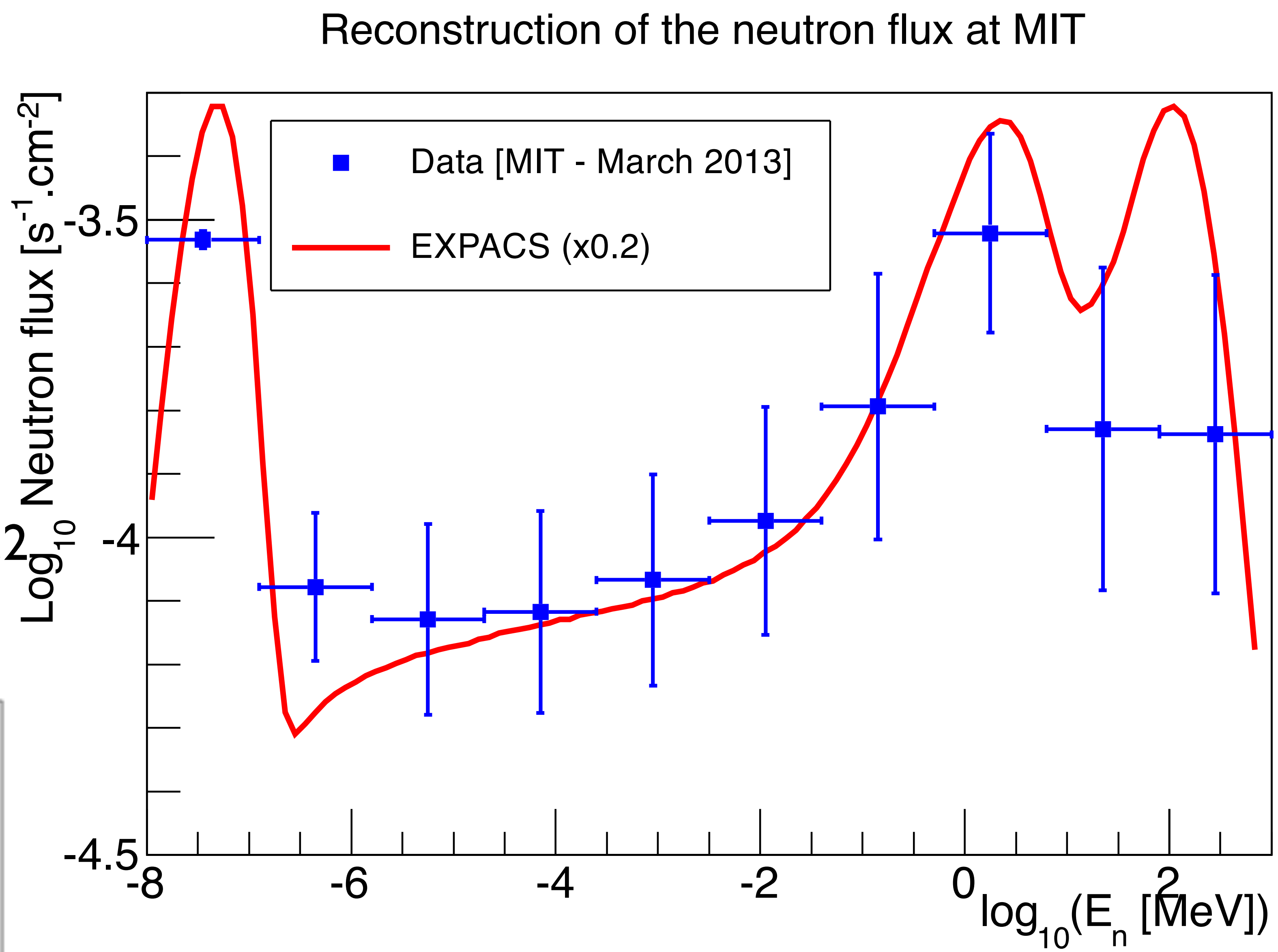


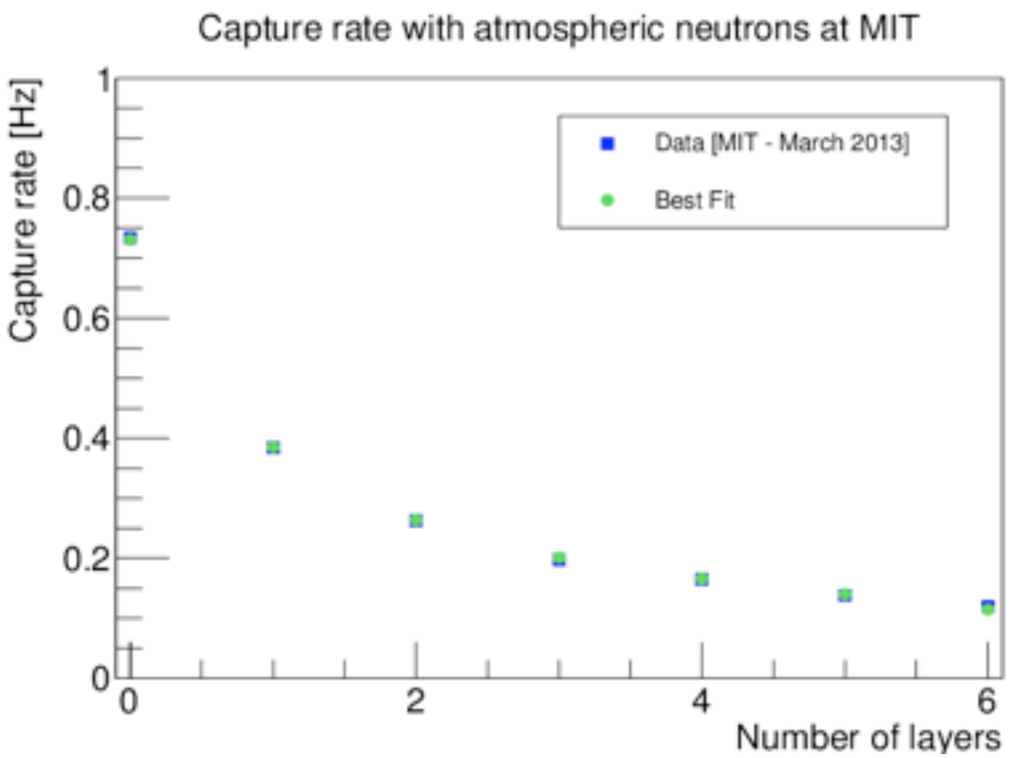
First run @ MIT

Likelihood based neutron flux reconstruction:

- Addition of a «shape prior»: 1/E
Justified by the high degeneracy between TF (study ongoing)
Widely used in CR physics and others

- Quality of fit very good: chi2/ndf = 0.2



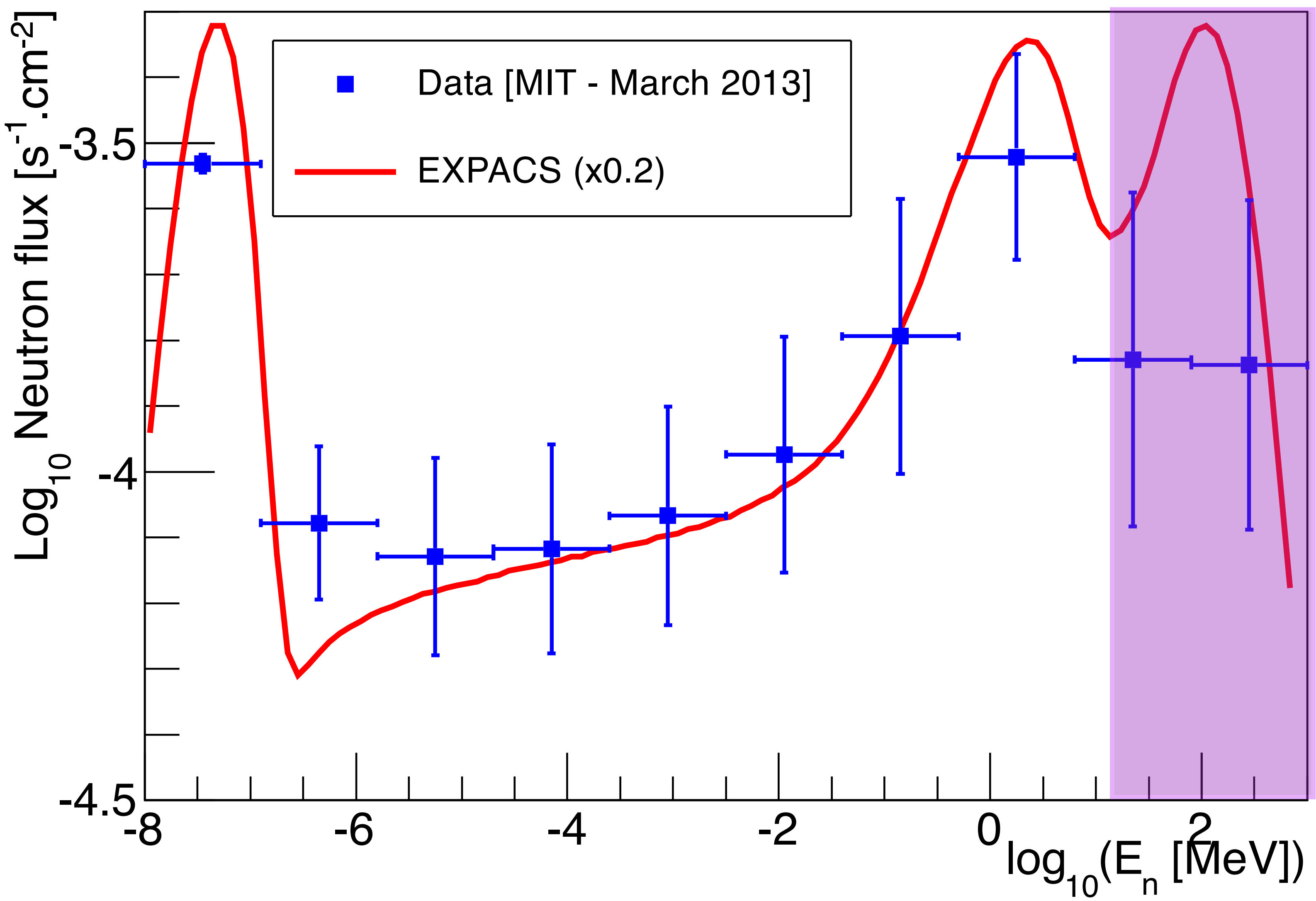


Total neutron flux @ MIT is about 10^-3 n/s/cm^2

We can measure neutron flux from 10^-8 to 10^2 MeV

Perspectives

Reconstruction of the neutron flux at MIT



Higher energy bins will always get higher error bars: **Addition of a He4 NCD?**

- He4 (Elastic Scatter) and He3 (Neutron Capture) should be complementary due their range of sensitivity and their opposite direction of neutron flux uncertainties propagation
- Will be tested with an AmBe source soon!