MACHe3: a prototype for non-baryonic dark matter search: keV event detection and multicell correlation

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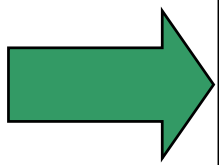
The Idea :

Use ^{3}He as a sensitive medium for the direct bolometric search of non-baryonic Dark Matter

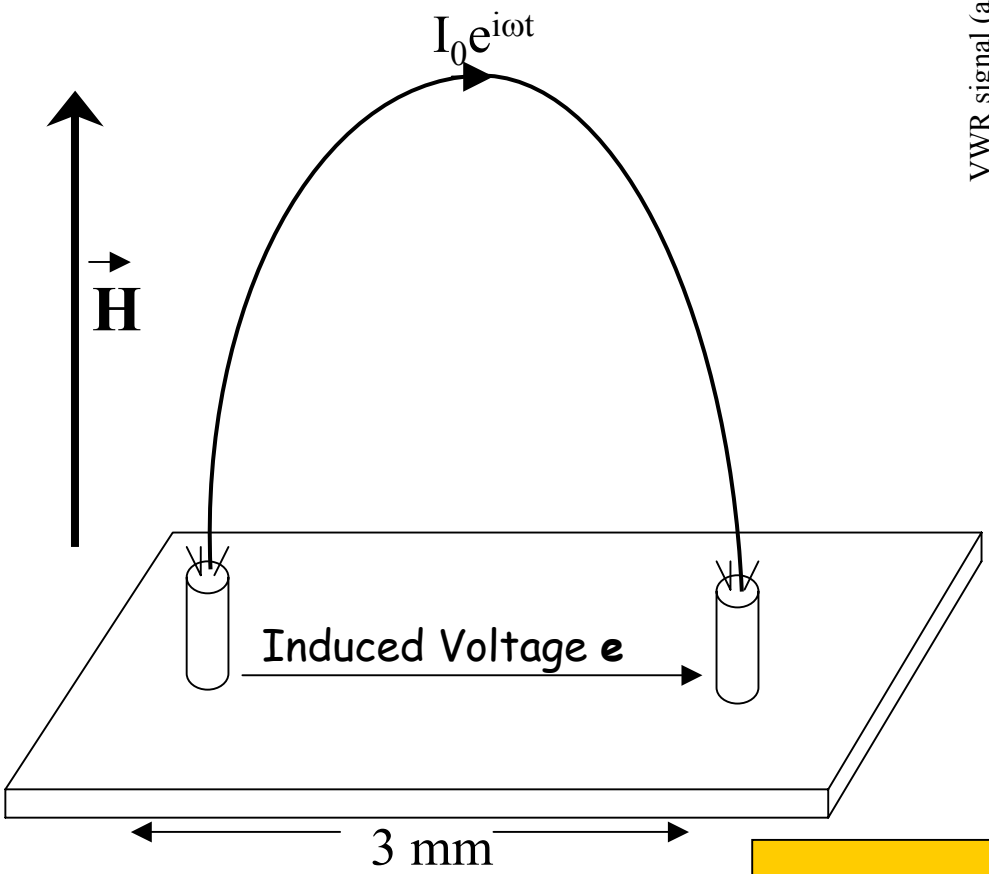
About ^{3}He :

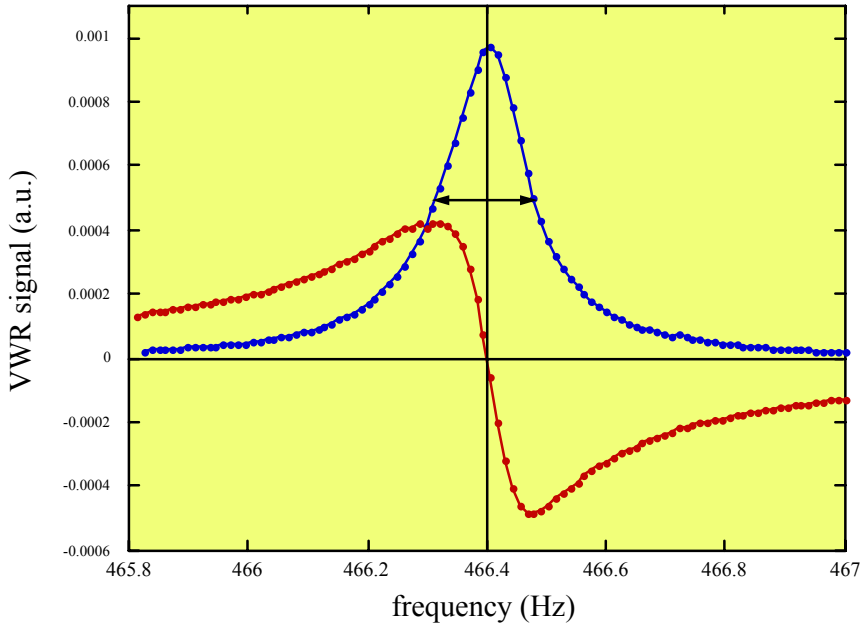
- spin $\frac{1}{2}$ nucleus
- liquid down to 0 K
- superfluid transition ~ 1mK
- extremely low heat capacity at low temperatures



Experimental temperatures of ~ 100 μK required

VWR thermometry in superfluid ^{3}He at 100 μK

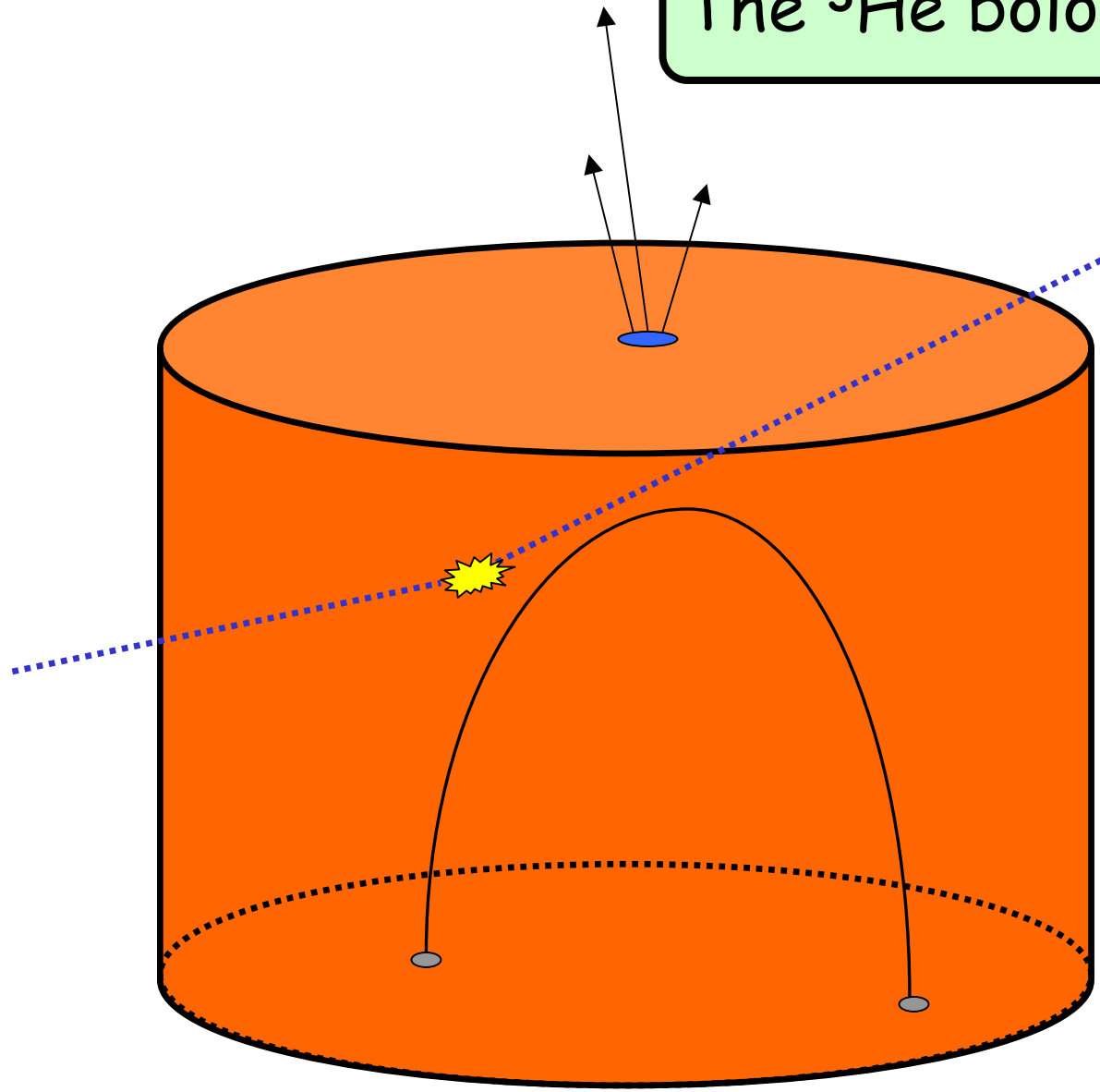




Damping due to interaction with quantum gas of quasi-particles of the superfluid
Fisher *et al.*, *PRL* (1989).

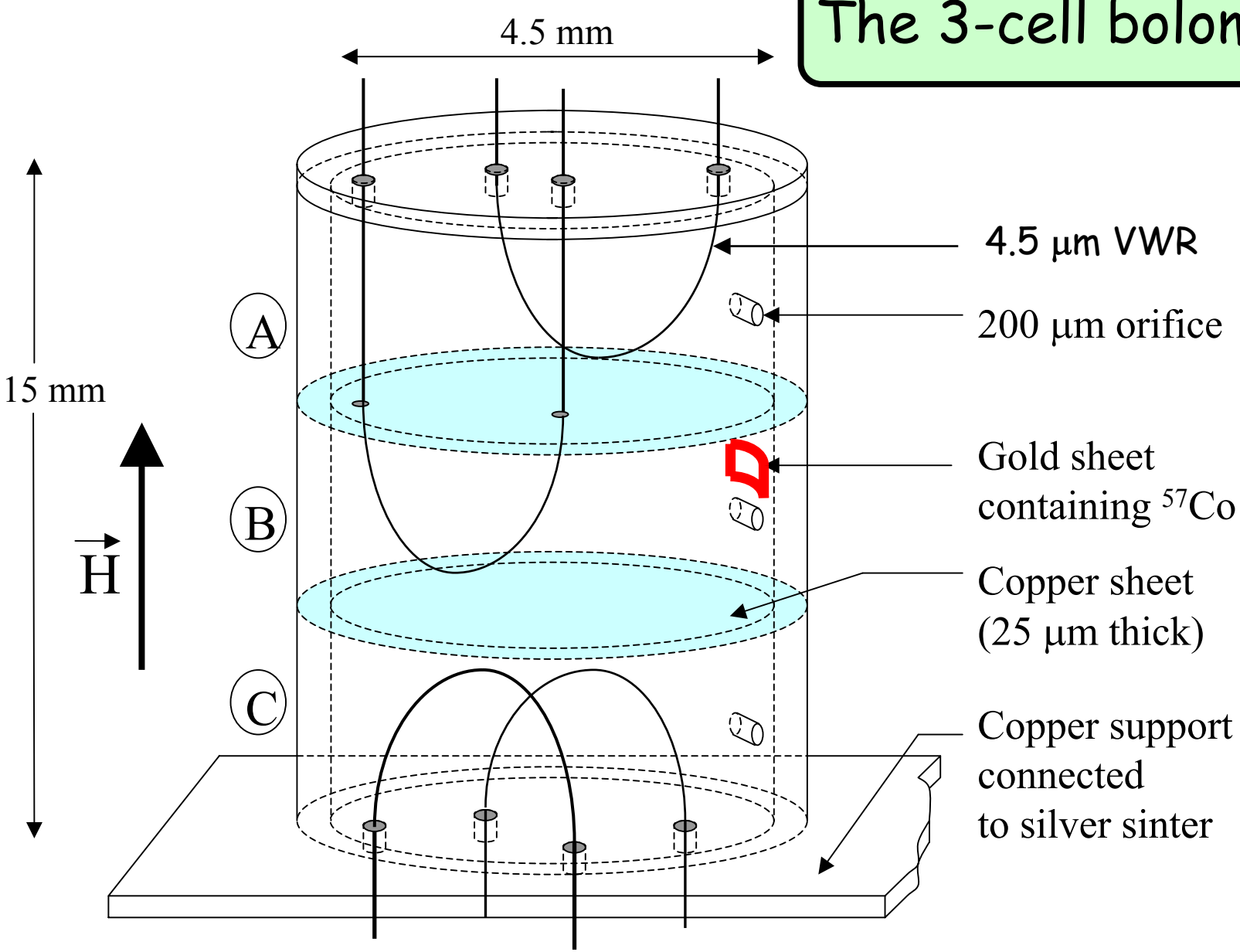
$$Damping \propto n_{qp} \propto \exp\left(-\Delta / k_B T\right)$$

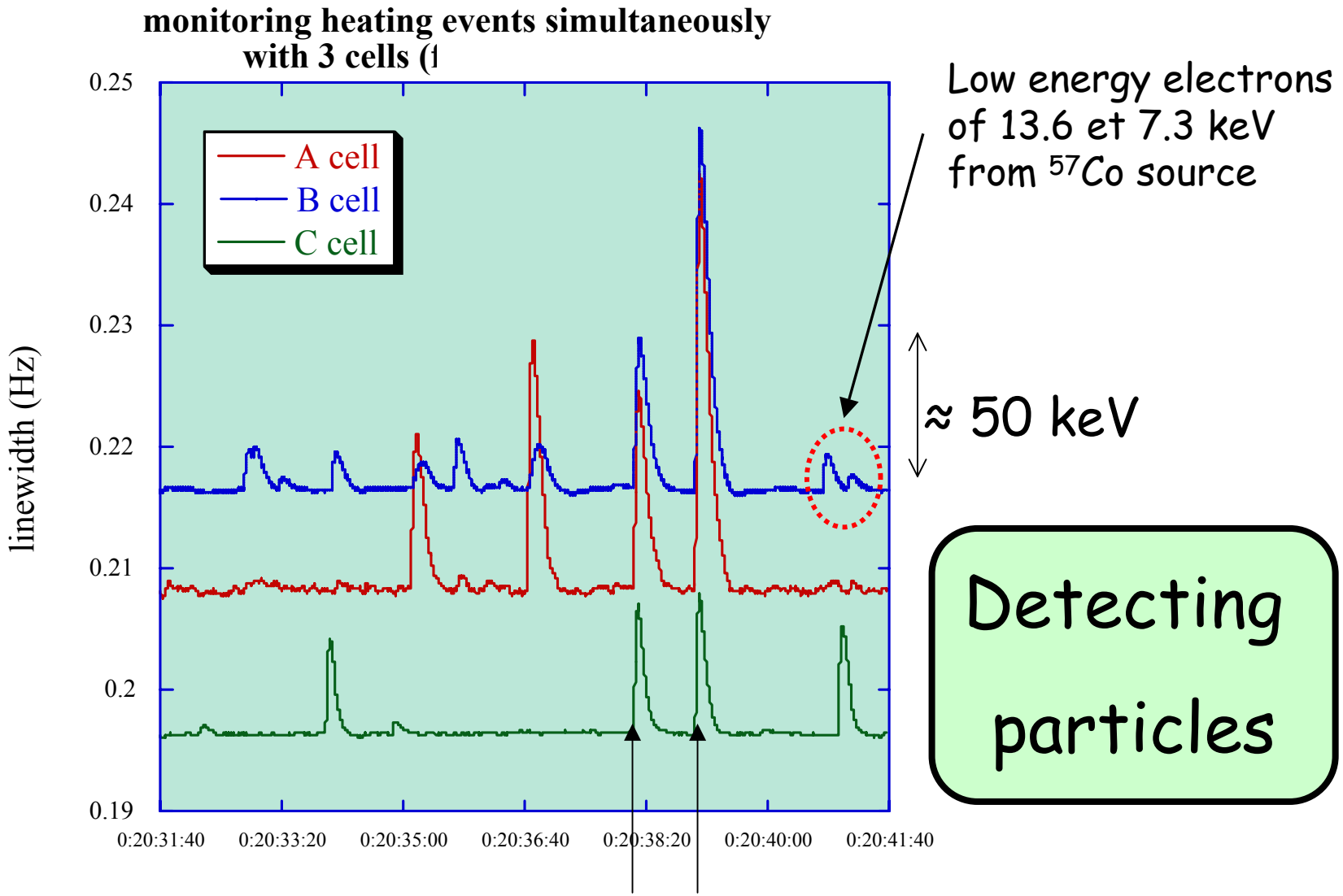
The ^{3}He bolometer



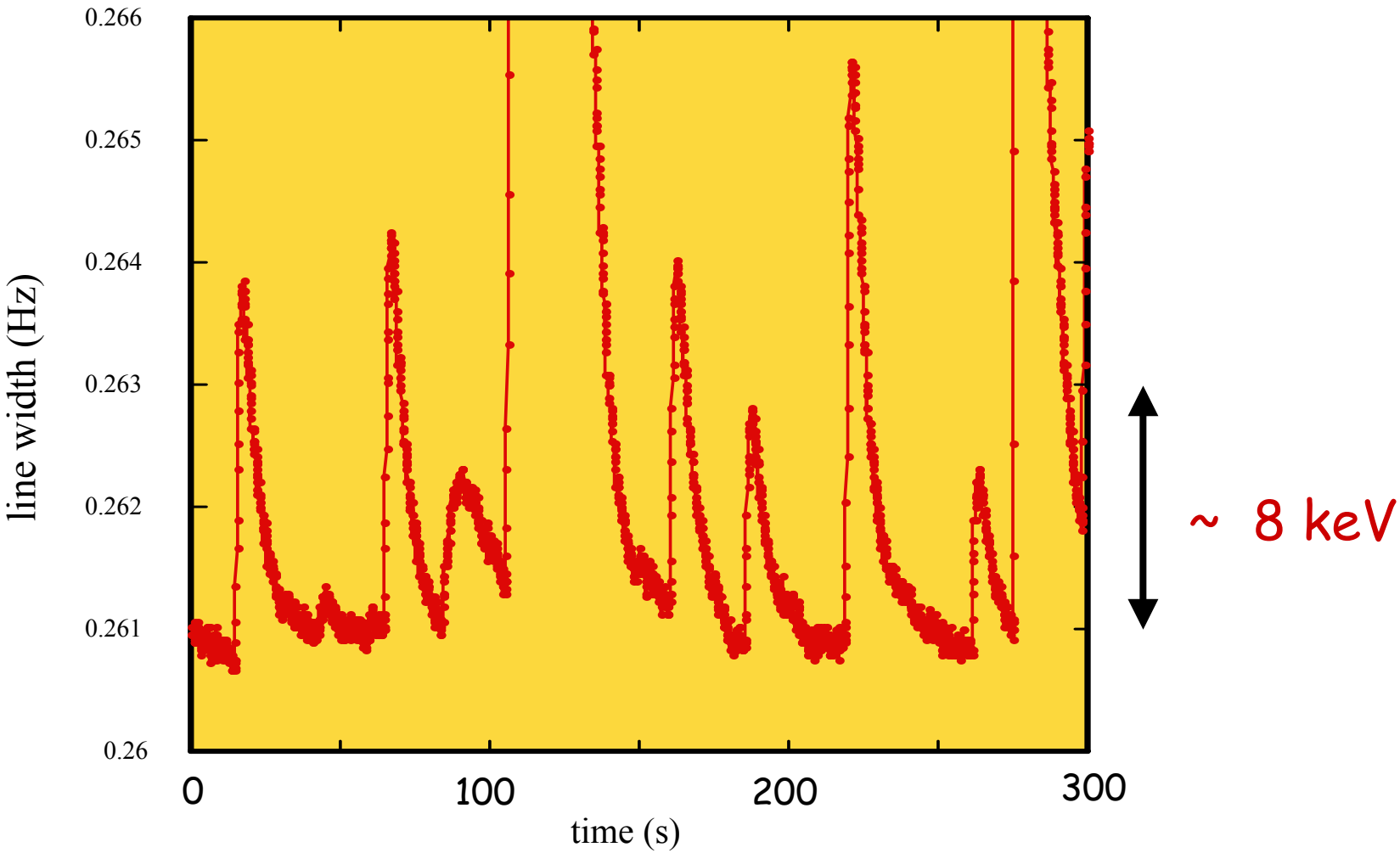
- Weak heat link to outer bath
- No heat leak through walls (Kapitza resistance)
- Direct *in situ* thermometry

The 3-cell bolometer

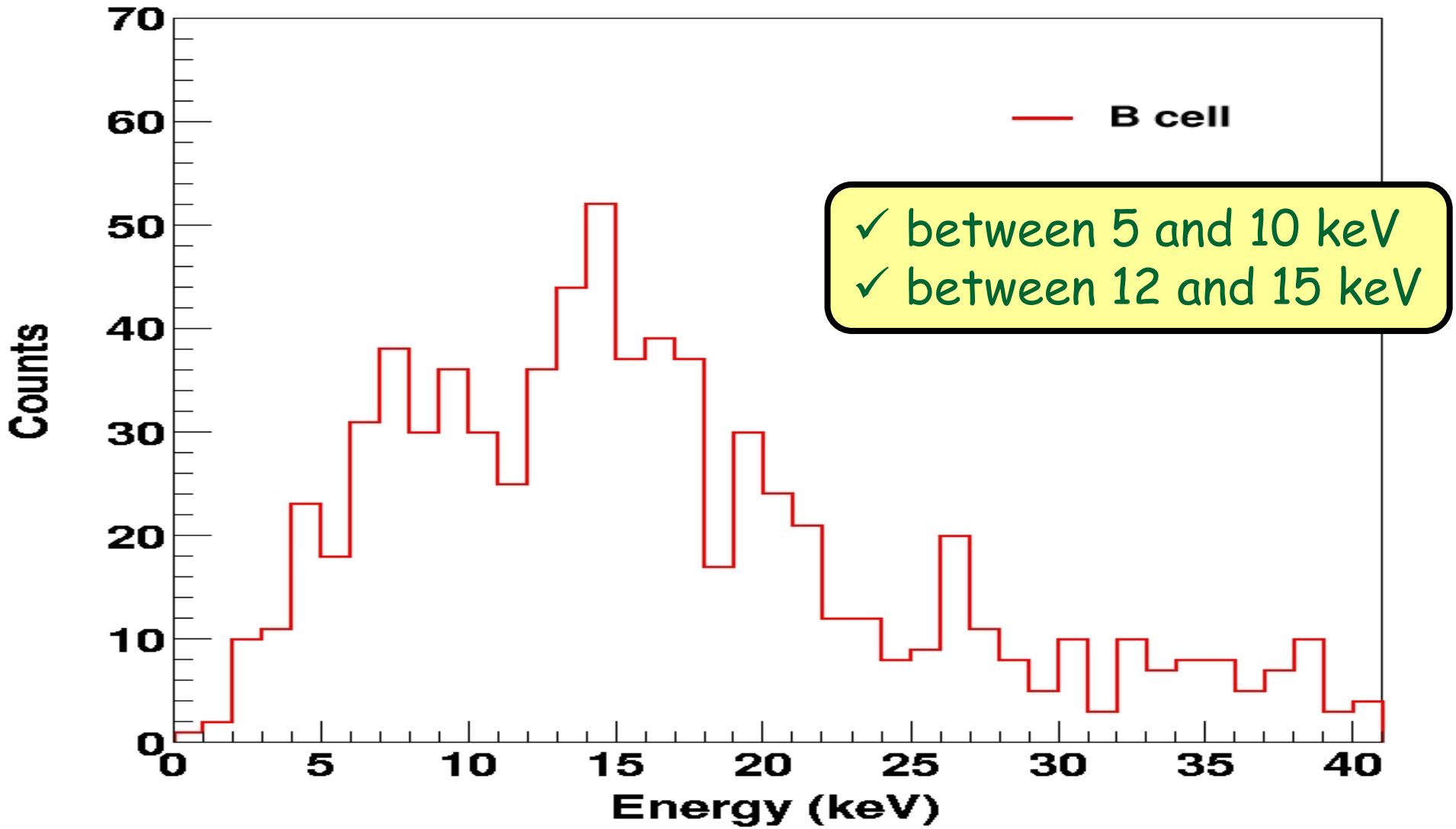



monitoring heating events simultaneously
with 3 cells (1
A cell
B cell
C cell
linewidth (Hz)
0.25
0.24
0.23
0.22
0.21
0.2
0.19
0:20:31:40
0:20:33:20
0:20:35:00
0:20:36:40
0:20:38:20
0:20:40:00
0:20:41:40
time
Low energy electrons
of 13.6 et 7.3 keV
from 57Co source
≈ 50 keV
Detecting
particles
Coincidence in all 3 cells

Internal conversion electrons in cell B



Low energy spectrum in the B cell from the ^{57}Co source (~0.1Bq)

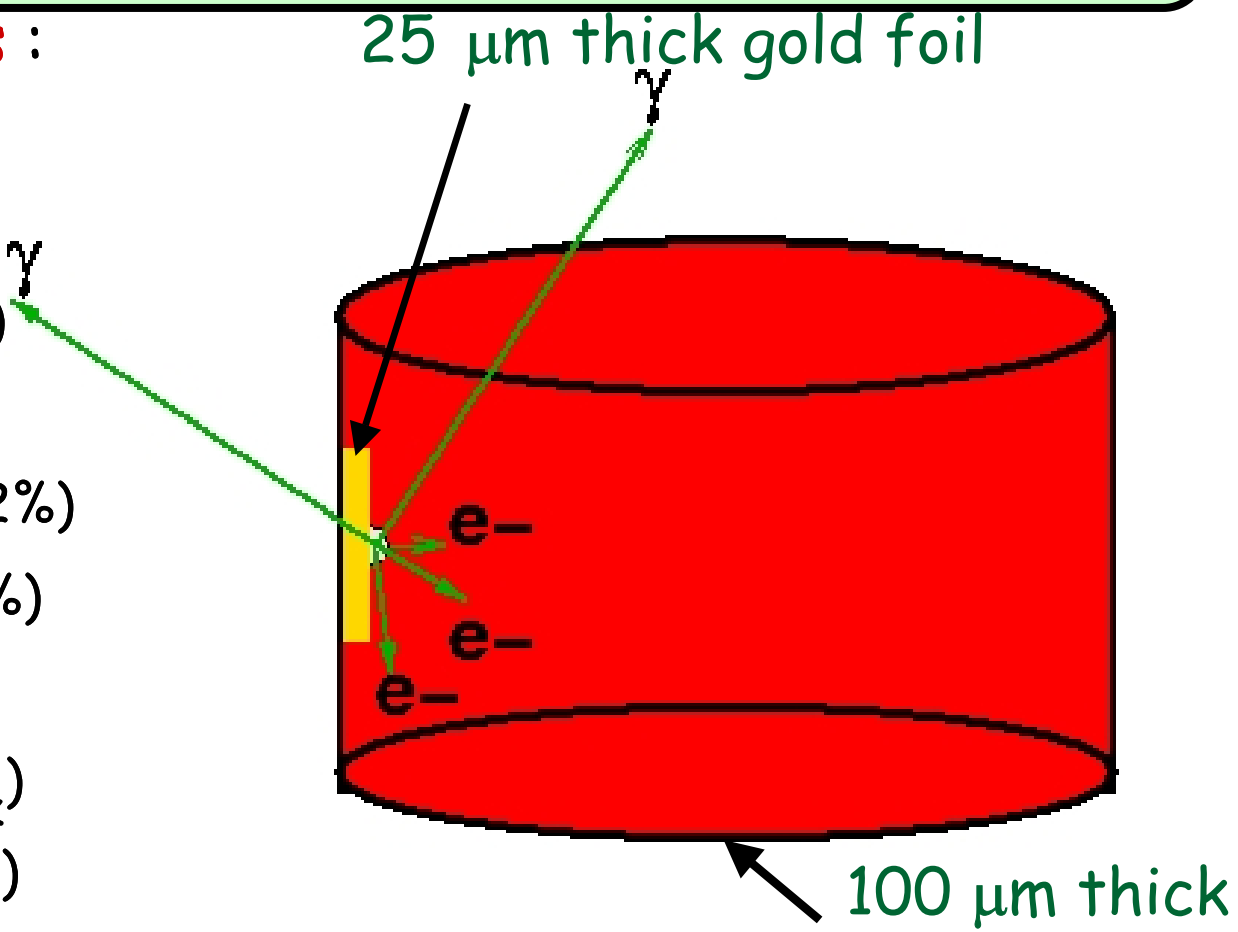


- ✓ between 5 and 10 keV
- ✓ between 12 and 15 keV

Expected electron spectrum from the low activity ^{57}Co source (~0.1Bq)

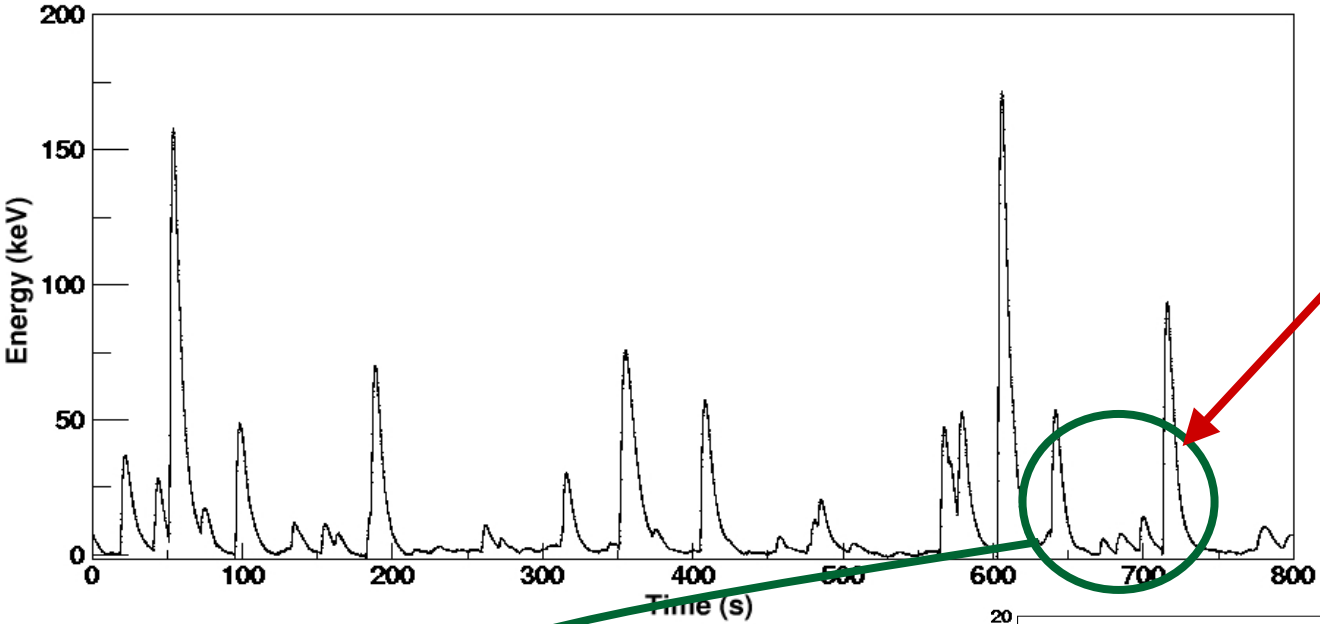
- conversion electrons :
  - ✓ 7.3 keV (K shell)
  - ✓ 13.6 keV (L shell)
  - ✓ 14.4 keV (M shell)
- auger electrons :
  - ✓ 5.5 keV (ω_K ~ 35.2%)
  - ✓ 0.6 keV (ω_L ~ 0.6%)
- pile-up :
  - ✓ 12.8 keV ($e_{c_K} + e_{A_K}$)
  - ✓ 14.2 keV ($e_{c_L} + e_{A_L}$)
  - ✓ 21.7 keV (gold $e_{A_L} + e_{c_K}$)
  - ✓ 27.9 keV (gold $e_{A_L} + e_{c_L}$)

} from 122 keV γ interaction in gold



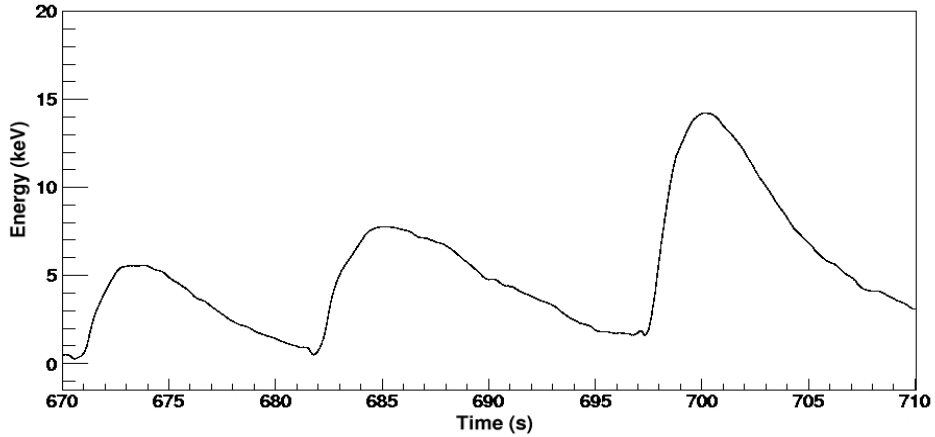
Raw data from the prototype at 100μK

- data from B cell where the ^{57}Co source is embedded



Low energy electrons

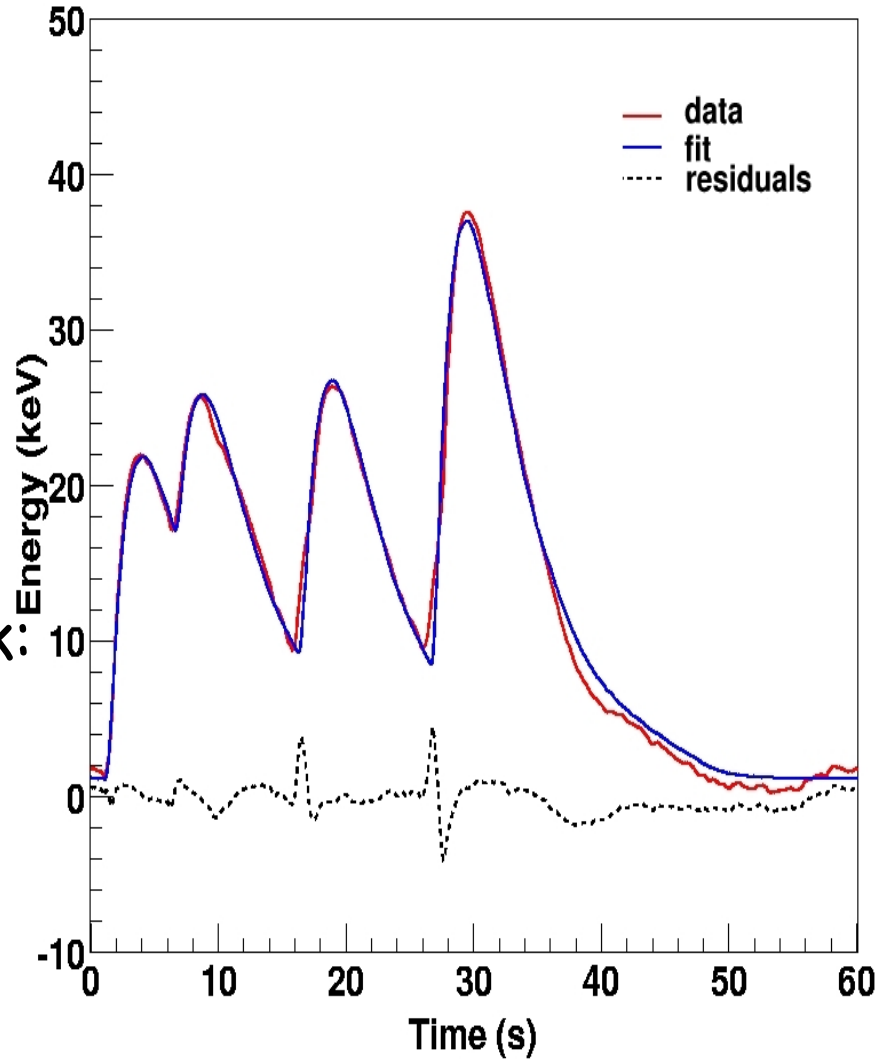
Electrons between 5.5 and 14.4 keV



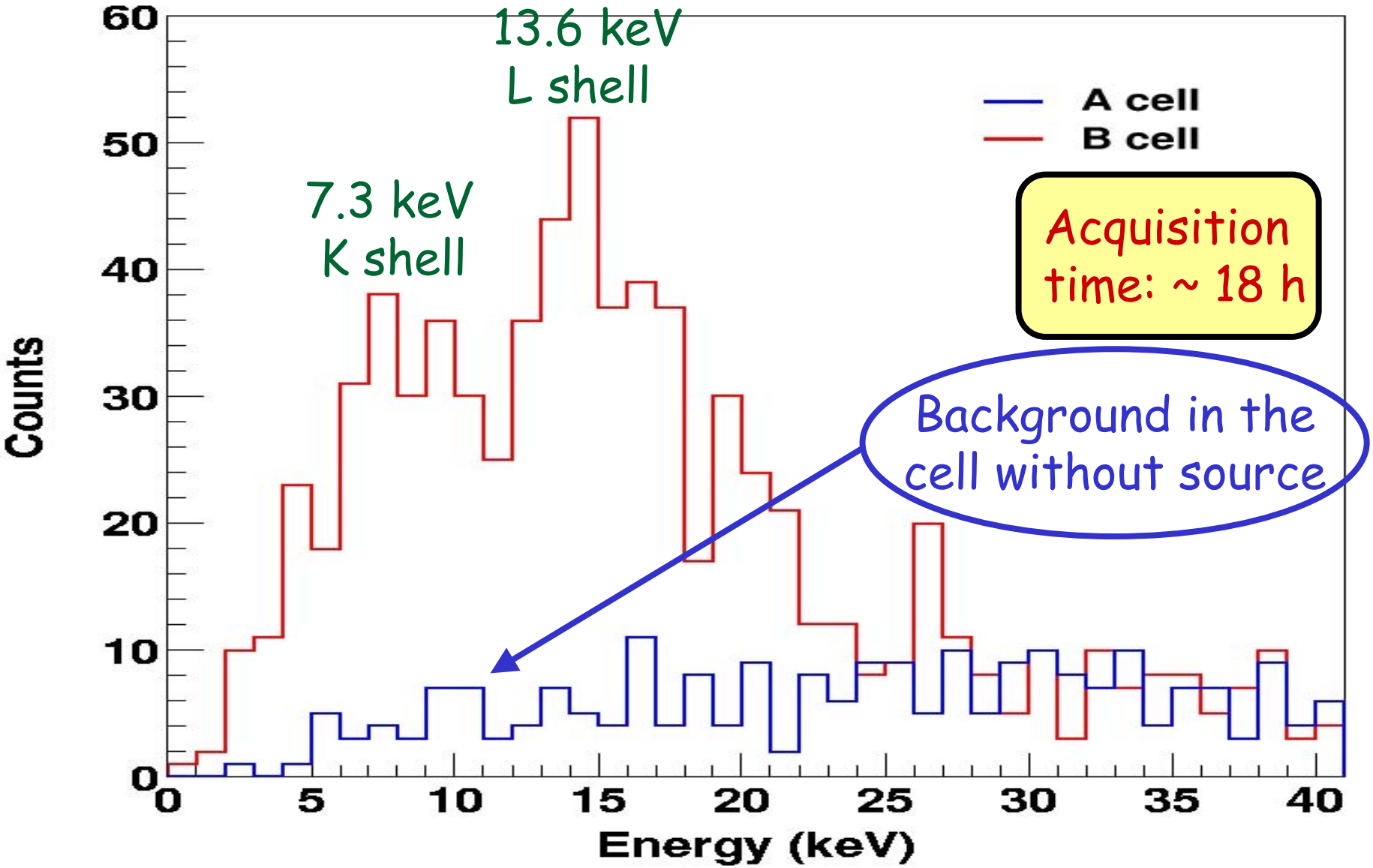
Analysis method

- Wavelet denoising
- Baseline removal
- Iterative fitting
  - Peak flagging
  - Fit to a reference peak
- Outputs for each detected peak:
  - ✓ position
  - ✓ amplitude
  - ✓ S/B

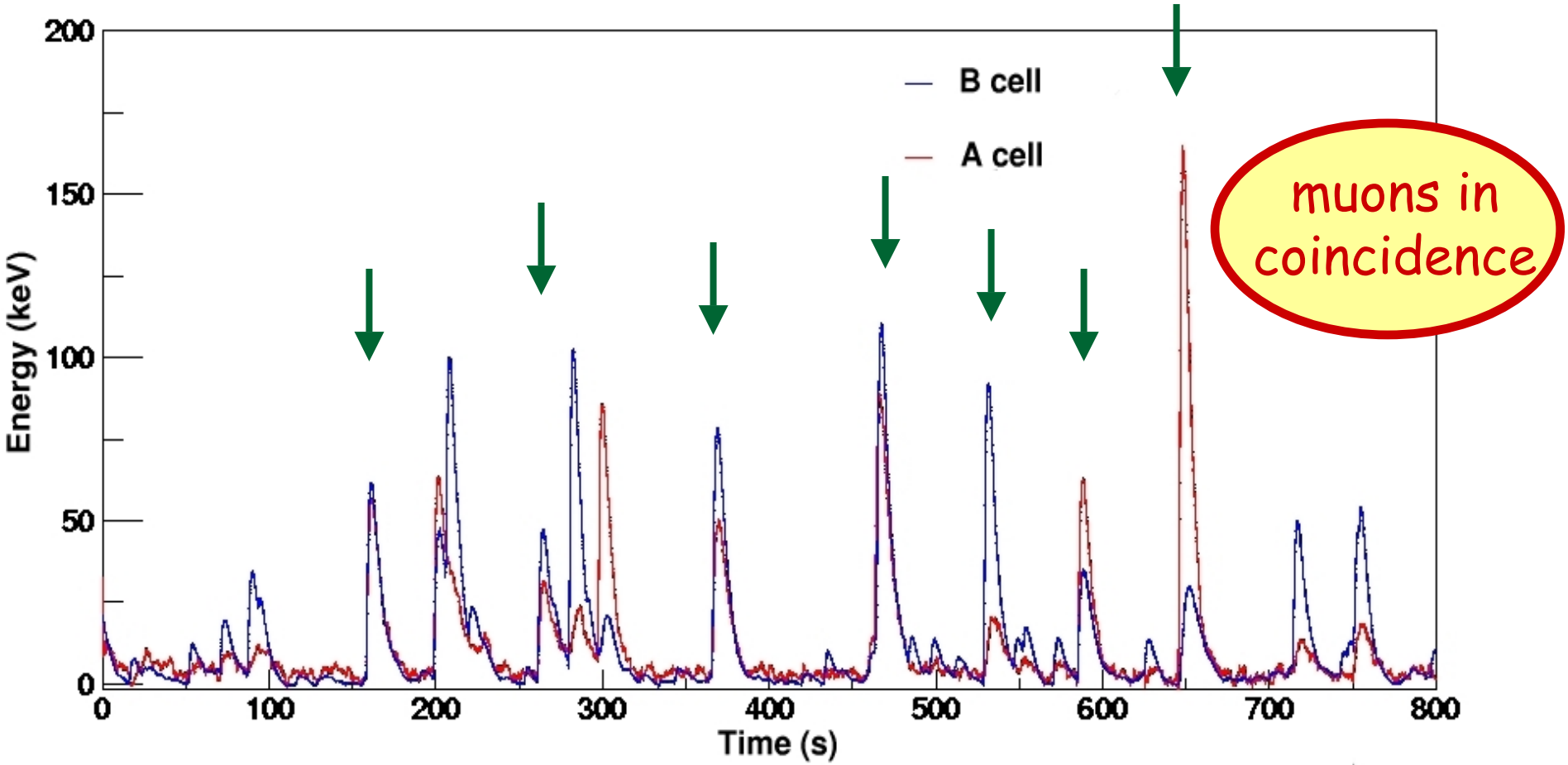
➢ we select peaks with **S/B ≥ 5**



Low energy electron spectrum in the B cell

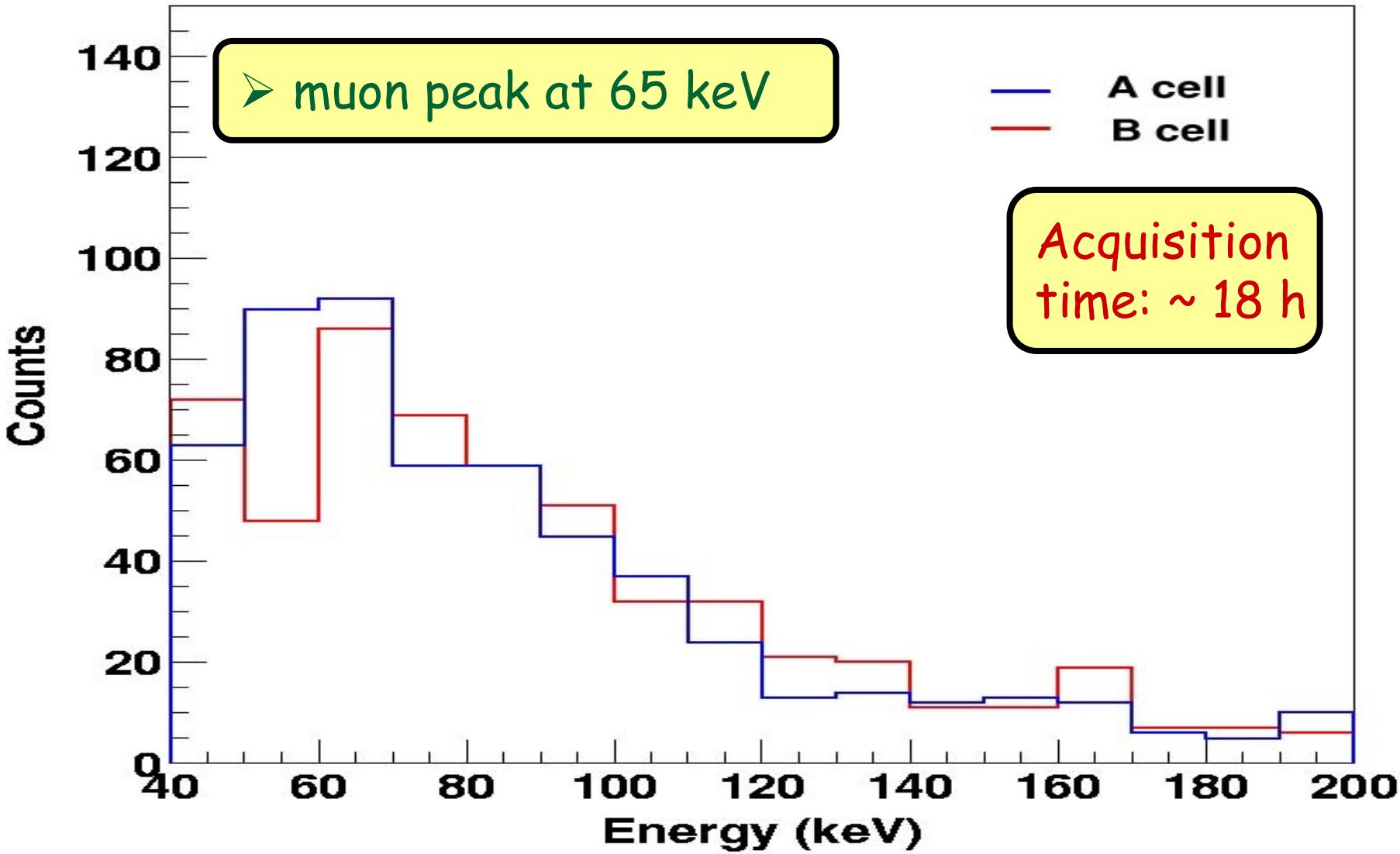


Correlation among two cells



- muons in coincidence among 2/3 cells, work in progress…
- good rejection of muons

Muon spectrum in A and B cells



^{3}He for non-baryonic dark matter search

- 1/2 spin nucleus $\Rightarrow$ axial interaction with neutralino
- neutron capture signature
- very low sensitivity to γ rays
- no intrinsic X rays
- threshold ~ 1 keV
- energy range < 6 keV
- sensivity to 2 GeV < m_W < 200 GeV

Main prototype results

- Development of high sensivity ultra-low temperature vibrating wire thermometry
- A working multicell prototype
- Detection in the keV range
- Correlation between the cells
- Measurement of cosmic muon spectrum
- Detection of low energy electrons (~ 7 keV)