

Counting Setup for Activation Measurements in Nuclear Astrophysics

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Workshop on Thermonuclear Reaction Rates and
Astrophysics Applications

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*Member of the Bonn-Cologne Graduate School of Physics and Astronomy

Motivation

- measurement of α -induced reactions
- experimental difficulties due to:
measurement at energies below the Coulomb barrier for heavy nuclei ($E_{\text{Gamow}} \approx 6 - 14 \text{ MeV}$)
- e.g. for $^{168}\text{Yb}(\alpha, \gamma)$: $E_{\text{Gamow}} \approx 7 - 11 \text{ MeV} \ll E_{\text{coul}} \approx 24 \text{ MeV}$

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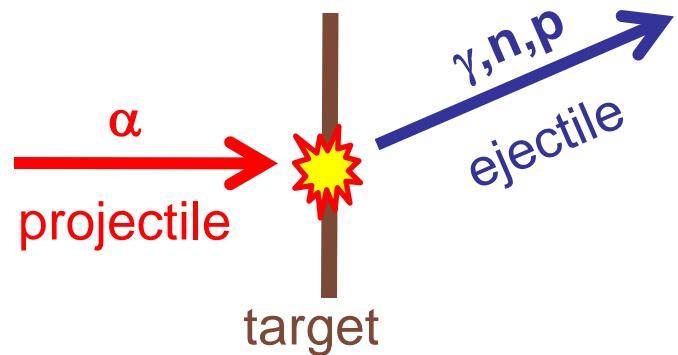
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A solution: activation measurements

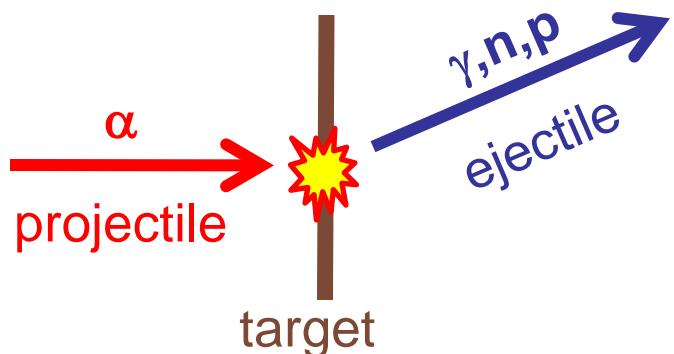
Activation experiments

1. Activation

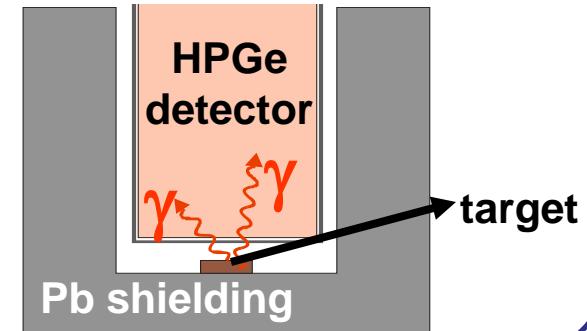


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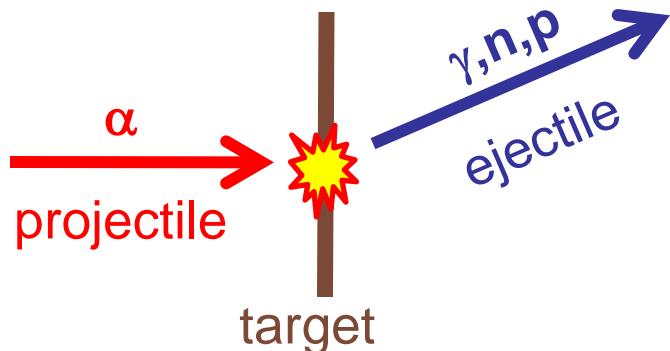


2. Counting

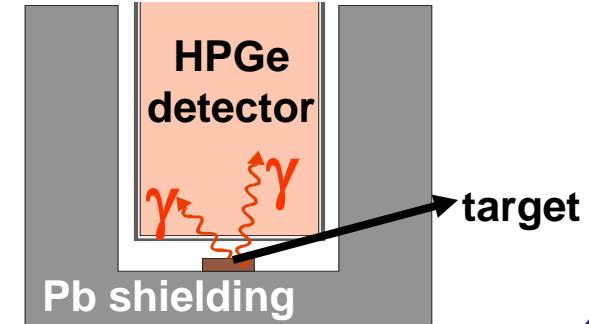


Activation experiments

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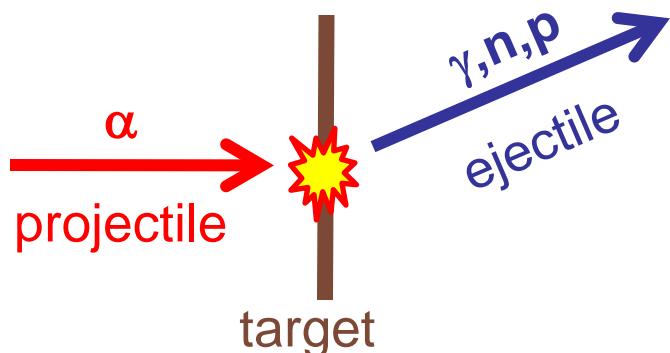


Advantages

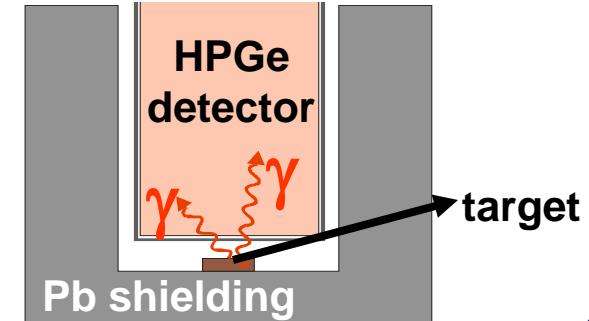
- ✓ very high beam intensities
- ✓ no beam-induced background
- ✓ strongly reduced background during counting

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2. Counting



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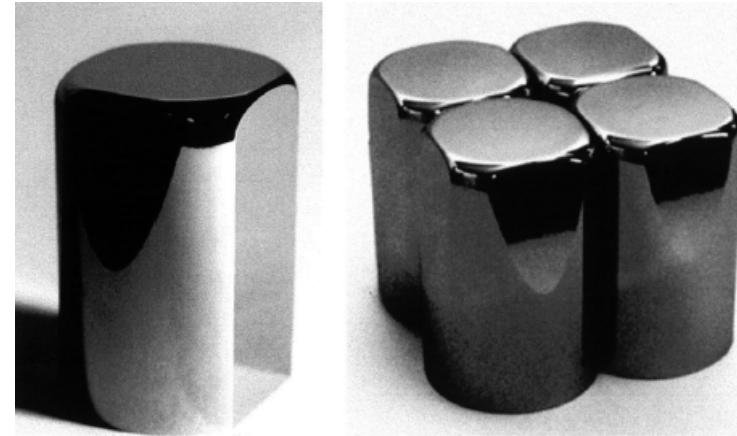
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Restrictions

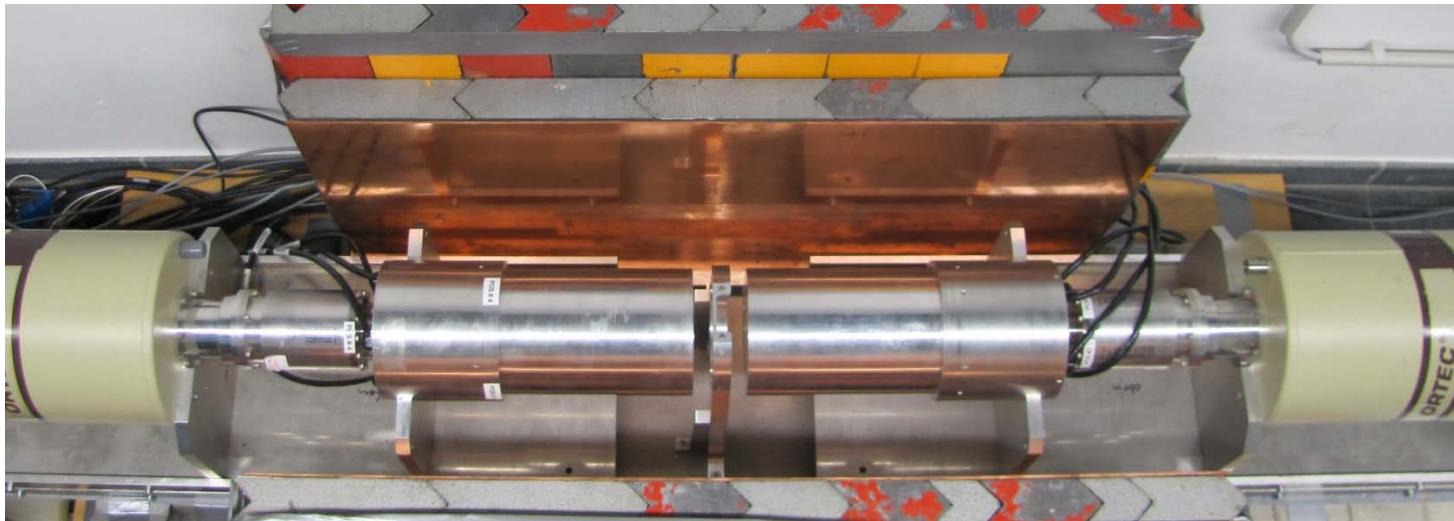
- ✗ unstable reaction products
- ✗ appropriate half-lives
- ✗ sufficient γ -intensity

Counting Setup

- 2 HPGe clover detectors
 - passive background suppression by Cu and Pb
 - covers large solid angle
 - allows $\gamma\gamma$ coincidences
- ➡ talk by A. Sauerwein

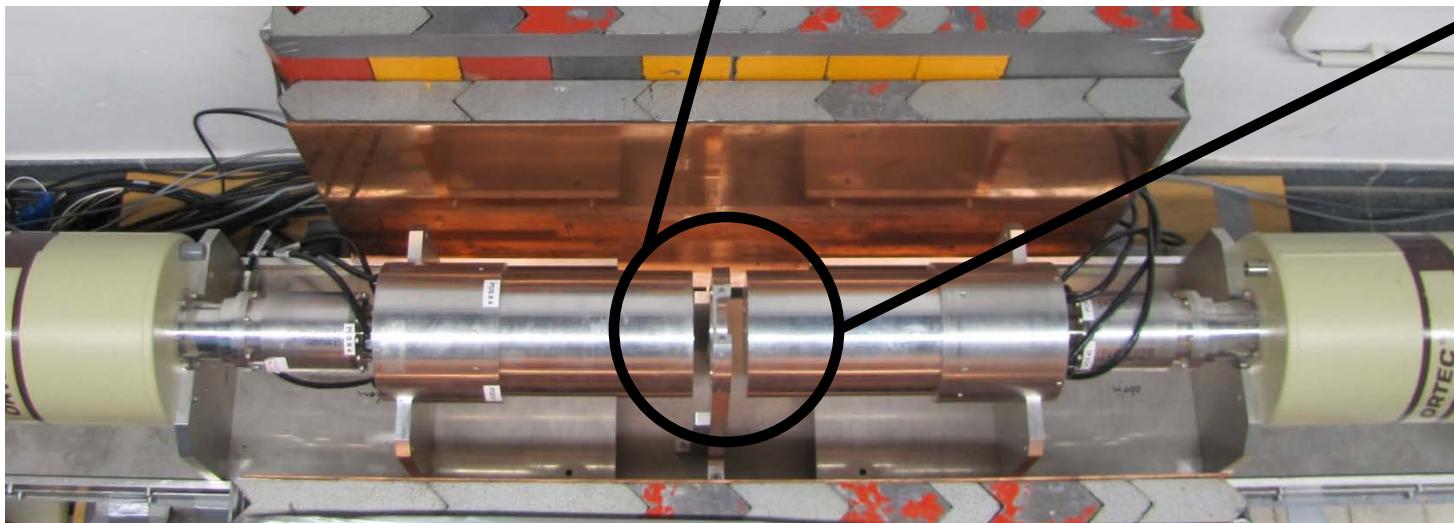
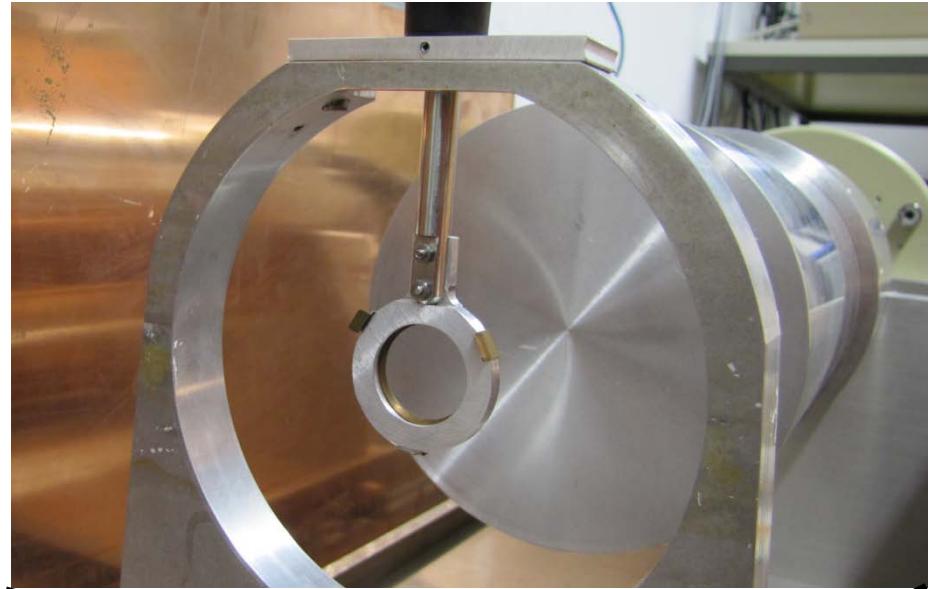


G. Duchêne et al.,
NIM A 432 (1999) 90-110



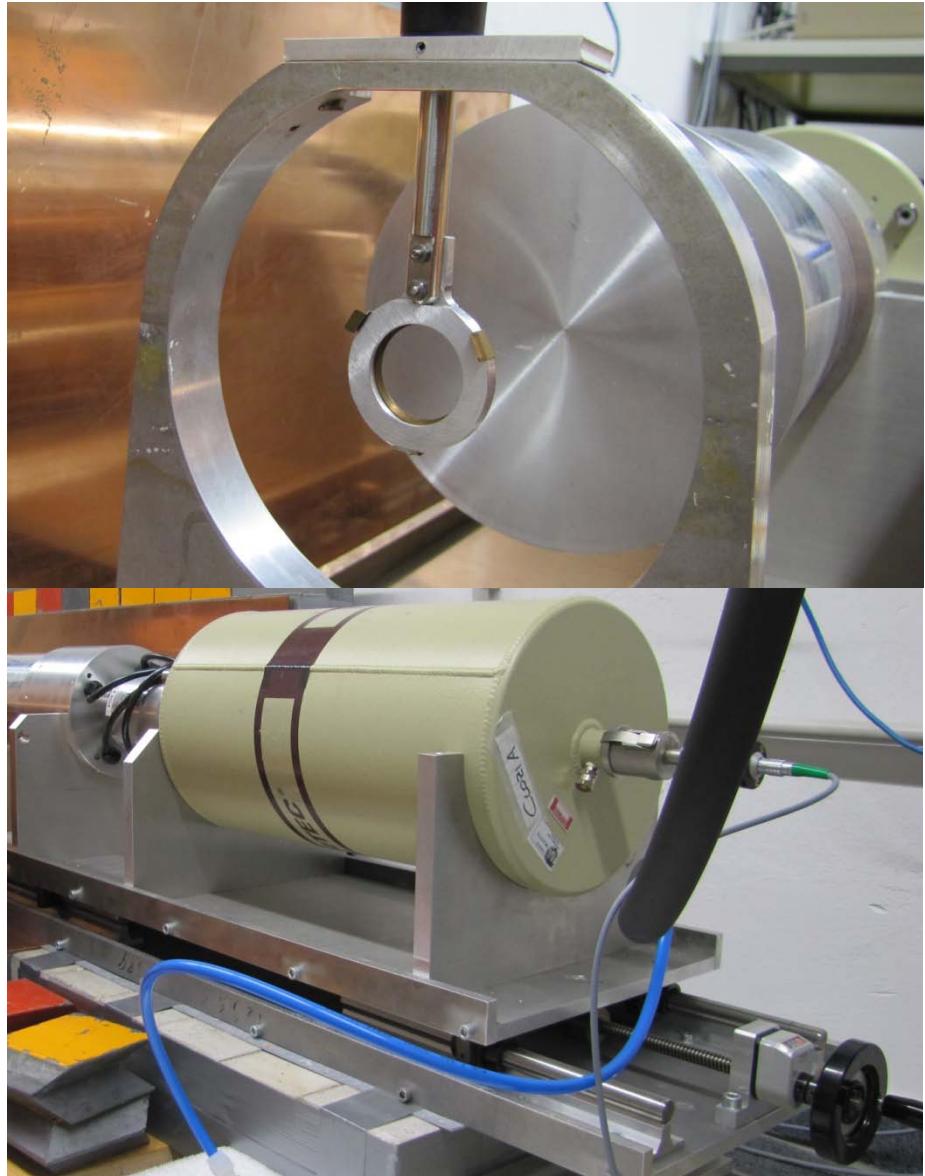
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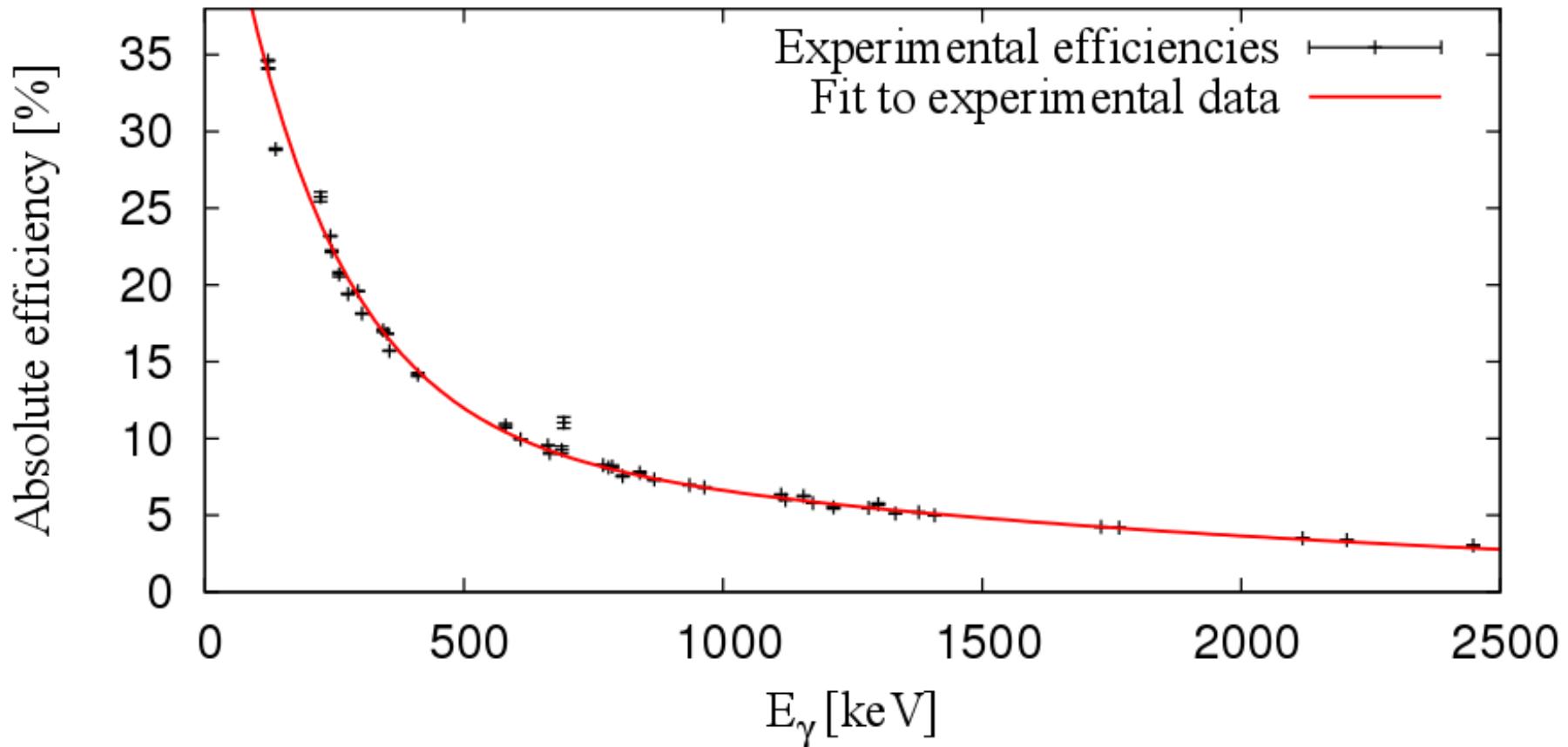


Counting Setup

- 2 HPGe clover detectors
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-
- different target geometries possible
 - accurate target positioning of 0.1 mm



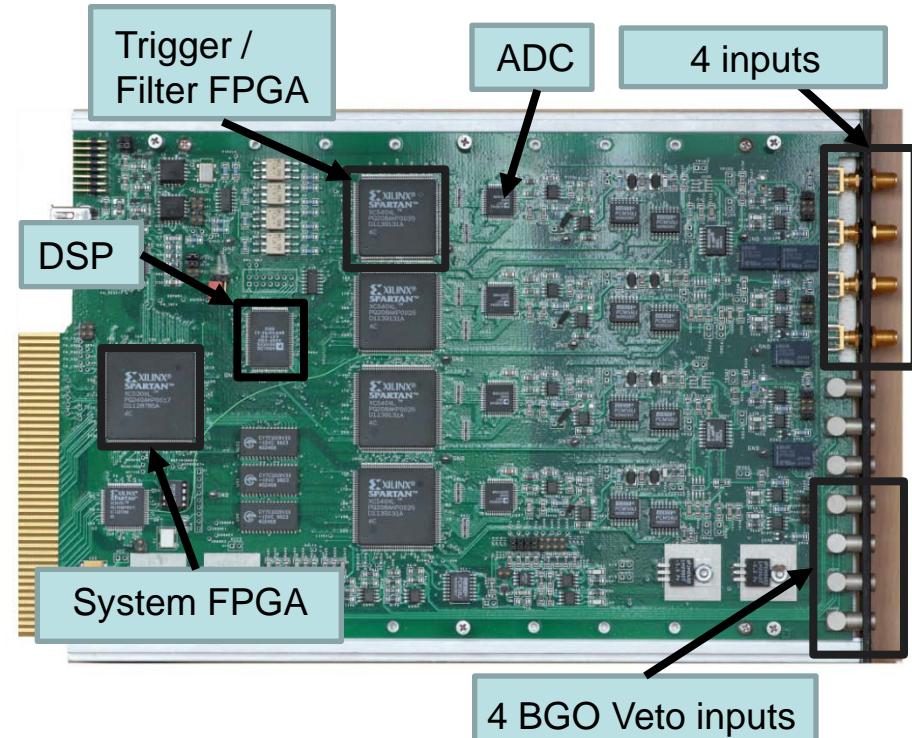
Counting Setup



- Absolute photopeak efficiency @ 1332 keV $\approx 5 \%$
- Distance to end cap: 13 mm

Data acquisition

- digital data acquisition
- XIA DGF-4C modules
- 14-bit Pipeline ADC
- sampling of preamplifier output at 80 MHz
- listmode data



XIA LLC, User's Manual Digital Gamma Finder DGF-4C
Revision F, Version 4.03

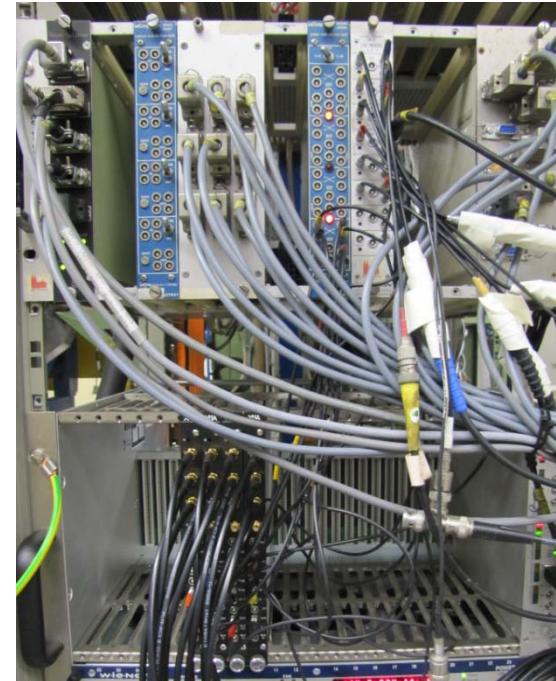
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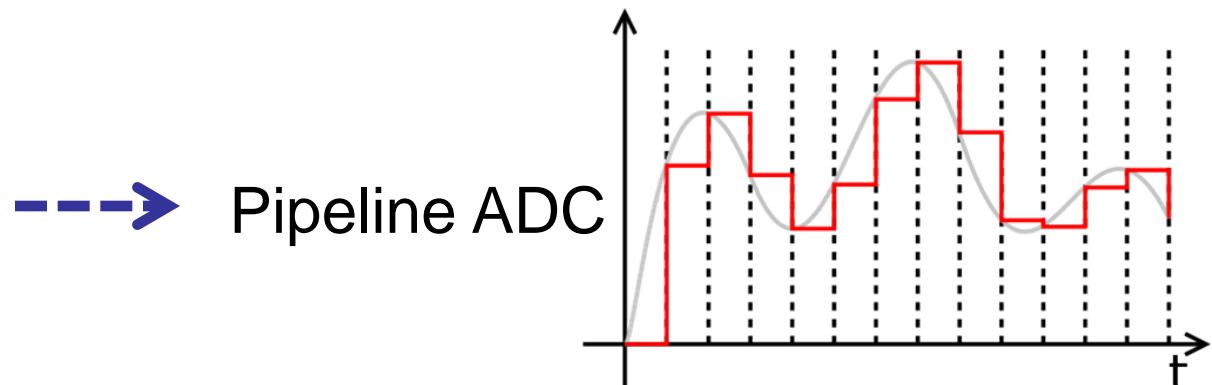
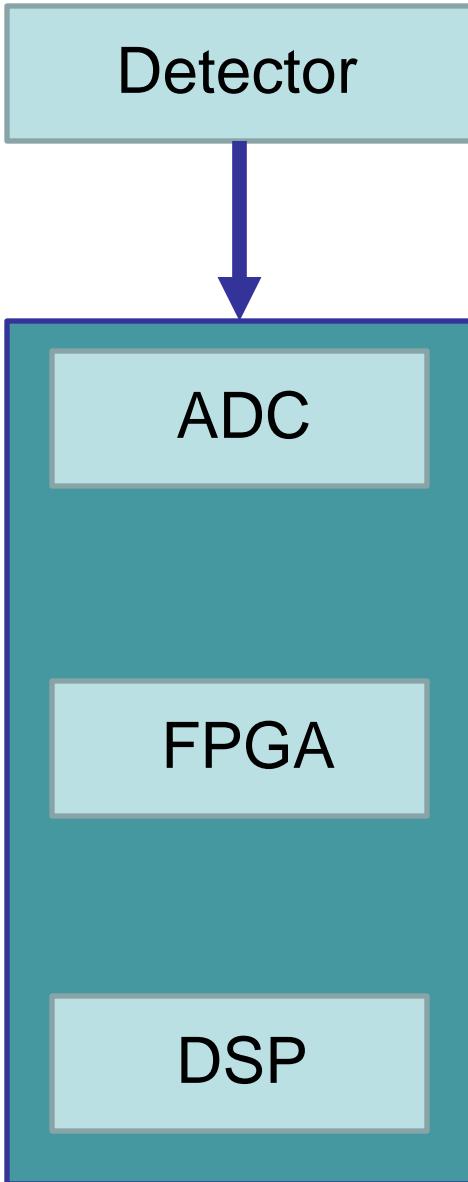


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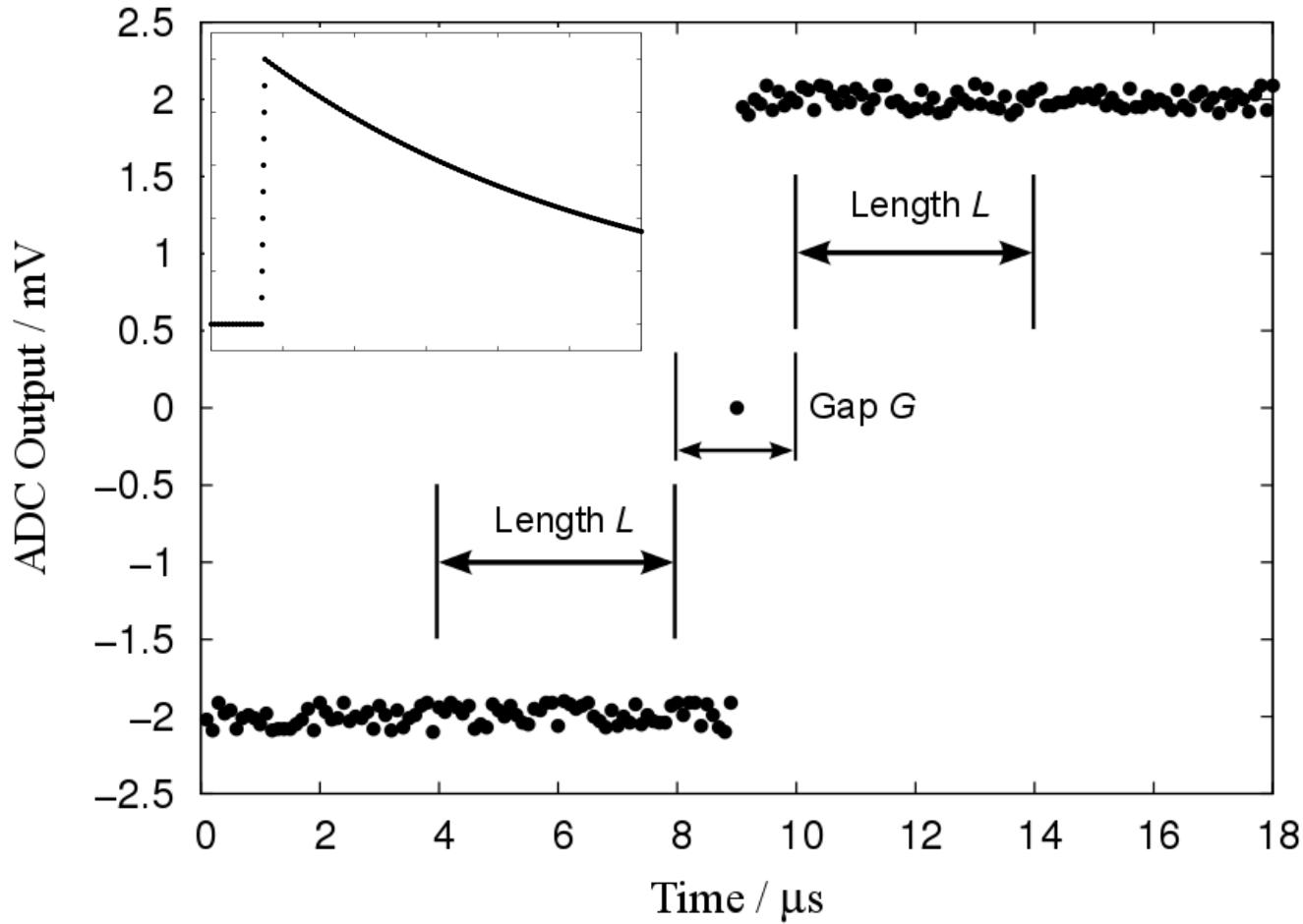


Digitizer – basic design



- **Pipeline ADC**
- **Field Programmable Gate Array**
→ applies filter algorithms
- **Digital Signal Processor**
→ determines energy and time

Trapezoidal filter algorithm

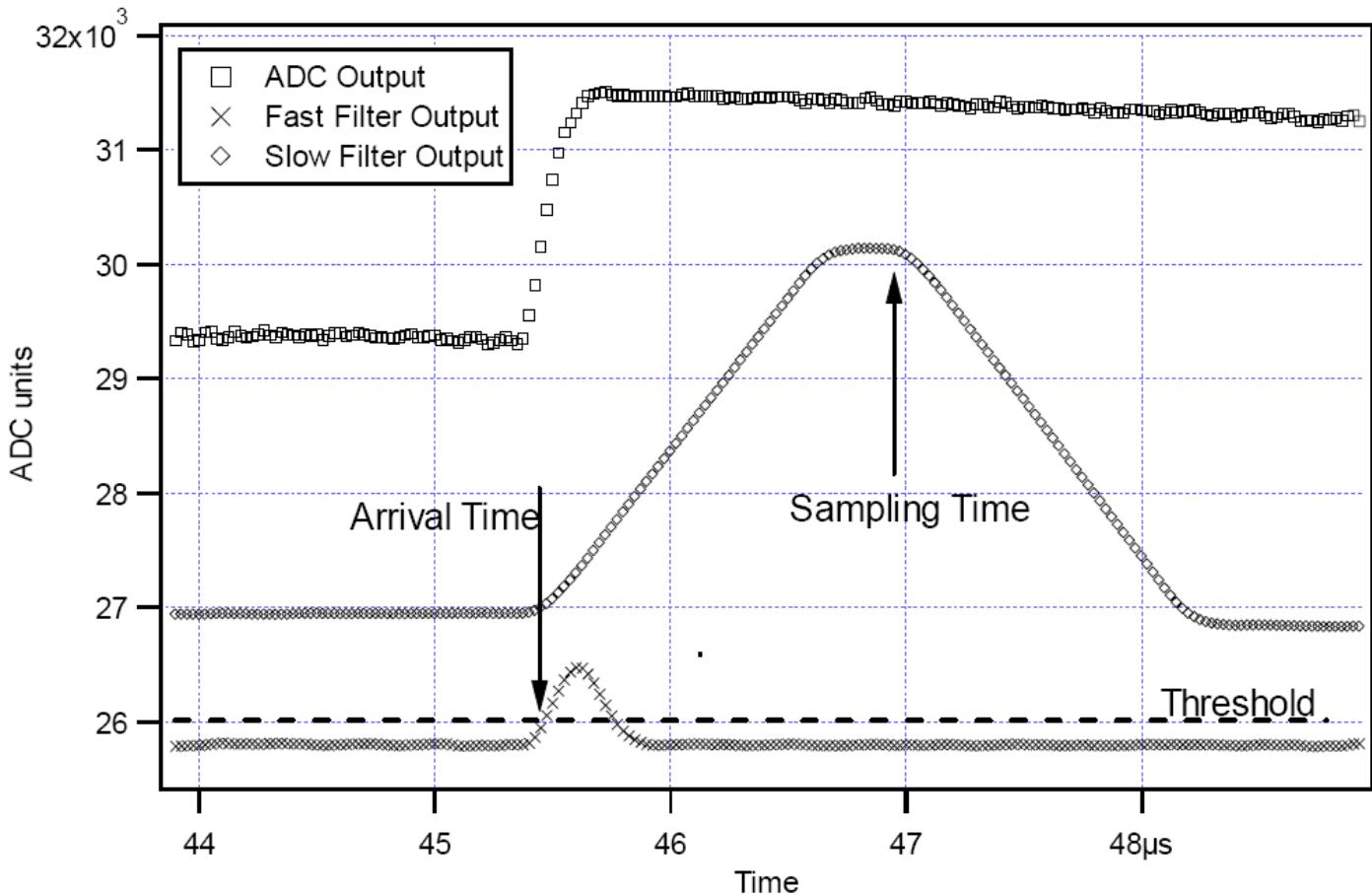


$$V_{x,k} = - \sum_{i(before)} W_i V_i + \sum_{i(after)} W_i V_i$$

XIA LLC, User's Manual Digital Gamma Finder
DGF-4C Revision F, Version 4.03

Fast and slow filter algorithm

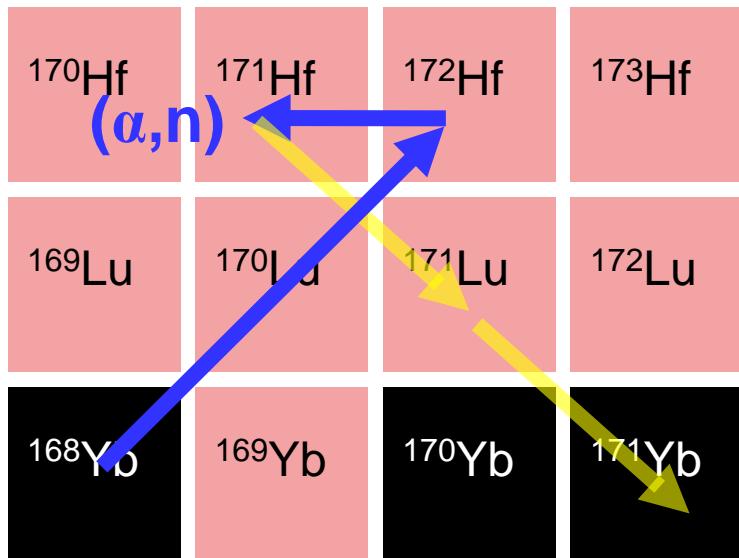
- fast filter → time determination
- slow filter → energy determination



XIA LLC, User's Manual Digital Gamma Finder
DGF-4C Revision F, Version 4.03

Activation measurement of $^{168}\text{Yb}(\alpha, n)$

- motivation: improvement of reaction network at ^{168}Yb

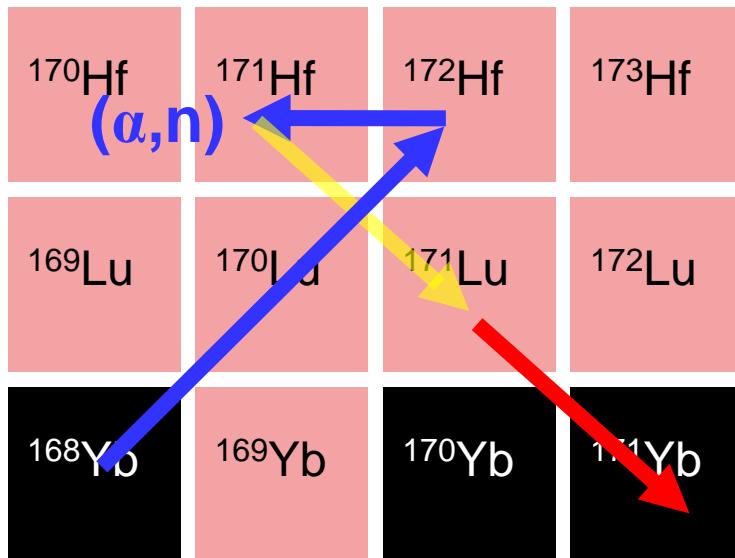


- $T_{1/2}(^{171}\text{Lu}) = 8.24 \text{ d}$
- target thickness = $230 - 450 \frac{\mu\text{g}}{\text{cm}^2}$
- activation period: 5 – 20 hours
- $E_\alpha = 12.9 - 15.1 \text{ MeV}$

measurement of $^{168}\text{Yb}(\alpha, n)$ to improve α -nucleus OMP

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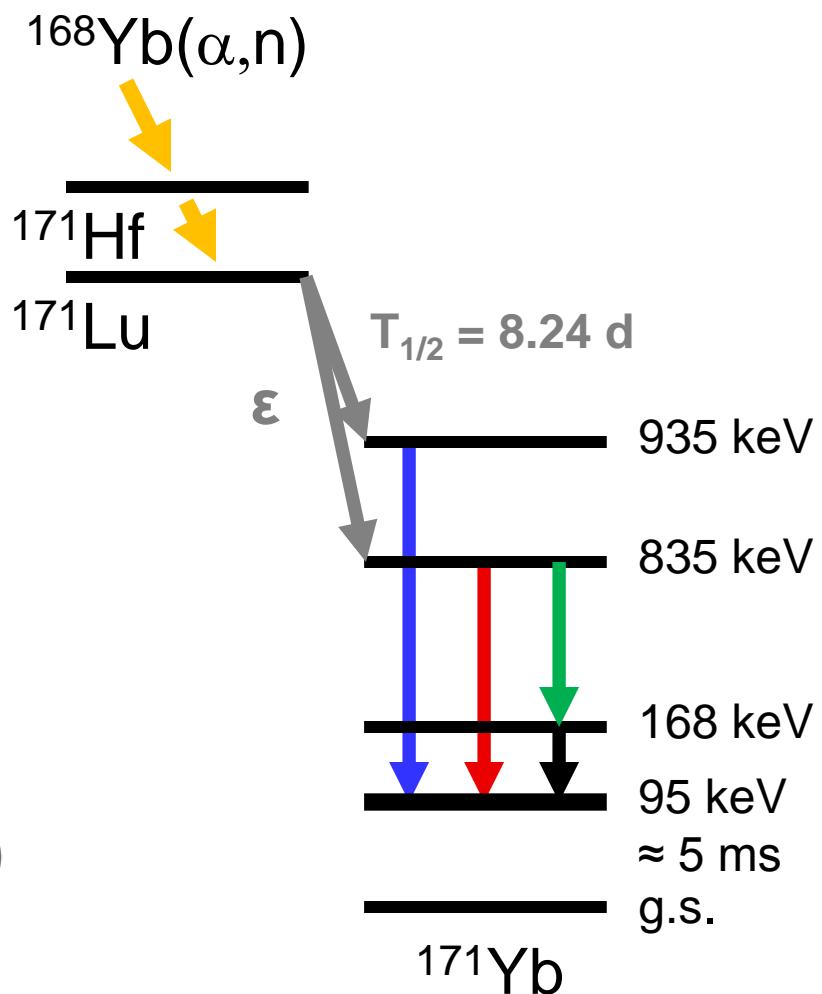
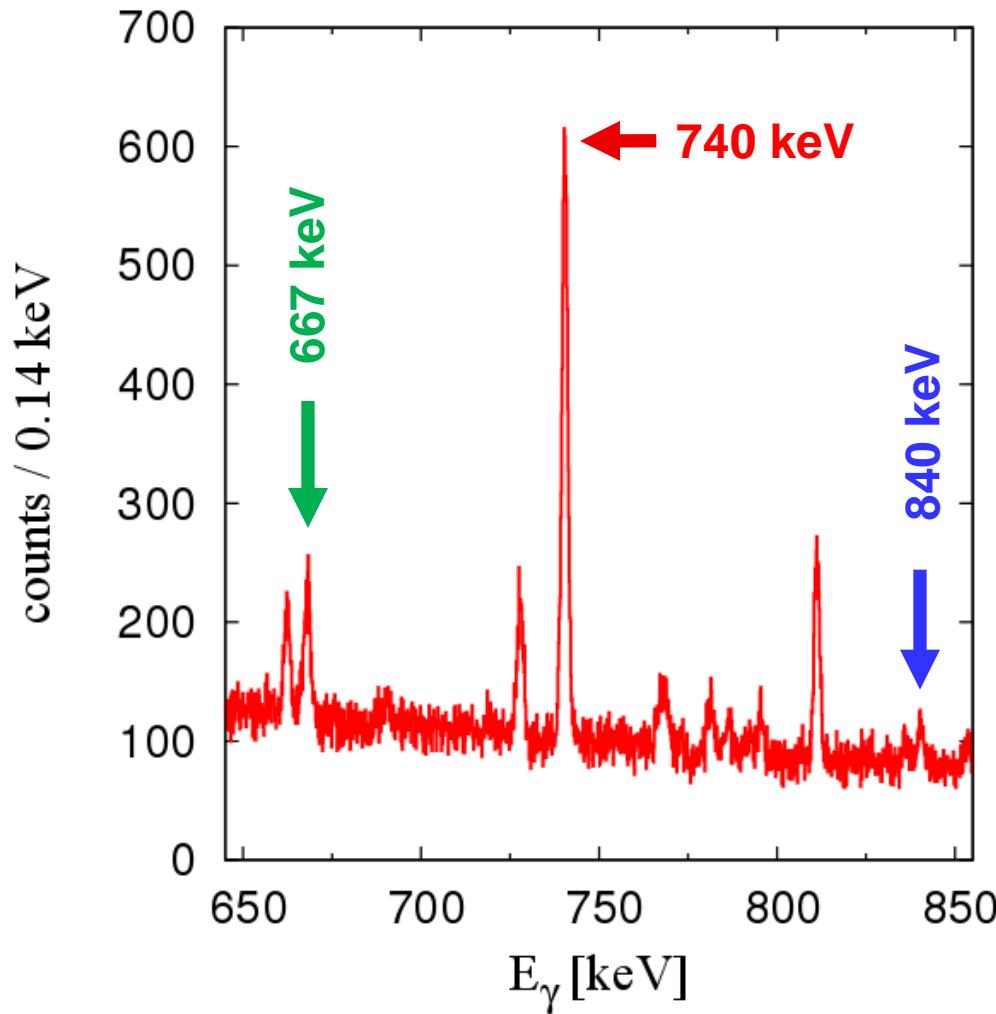
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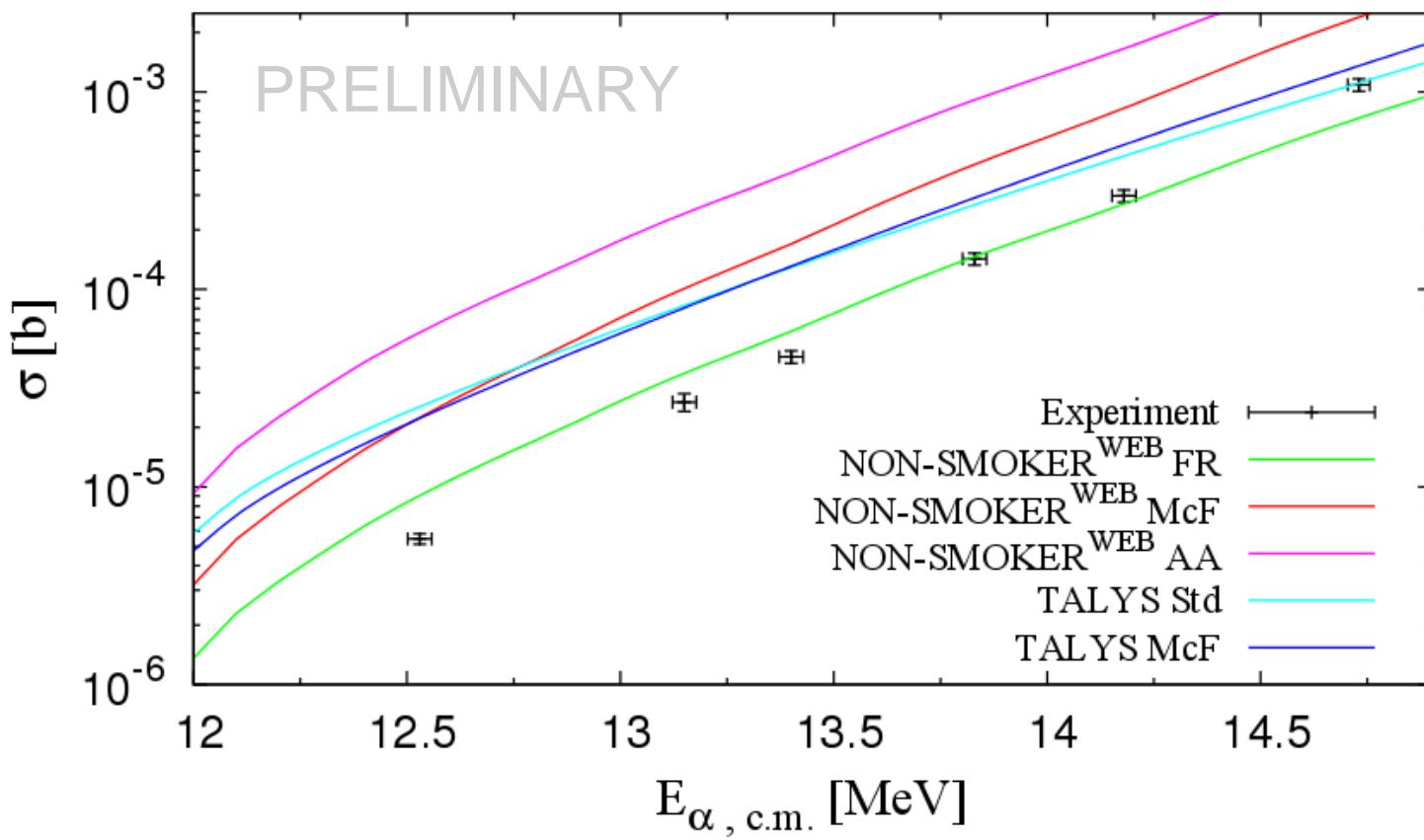
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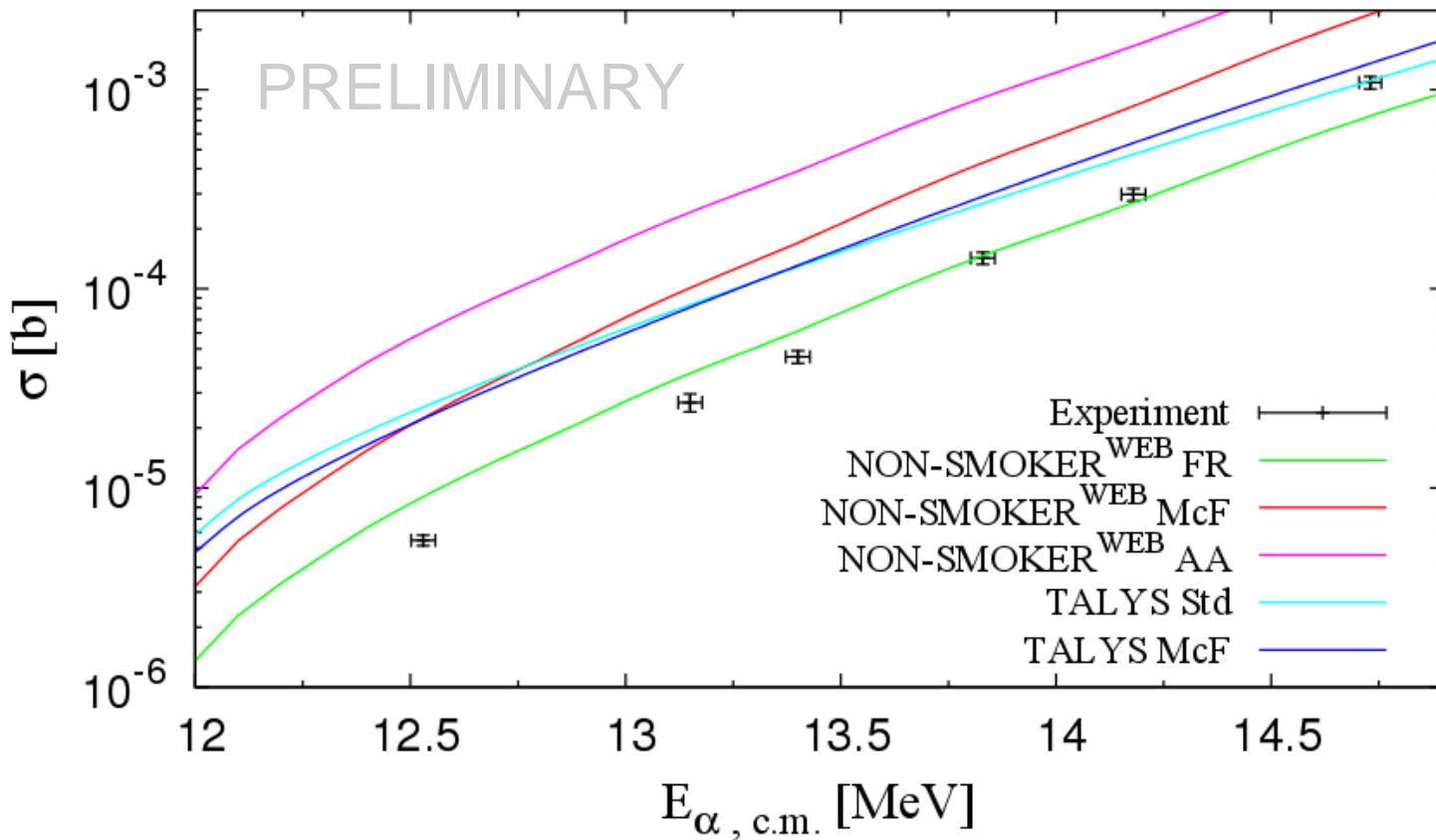
- $E_\alpha = 14.55 \text{ MeV}$
- counting period $\approx 23 \text{ h}$

Results: $^{168}\text{Yb}(\alpha, n)^{171}\text{Hf}$



T. Rauscher, NON-SMOKER^{WEB}, 5.8.1dw
A.J. Koning, S. Hilaire and M.C. Duijvestijn, TALYS-1.2

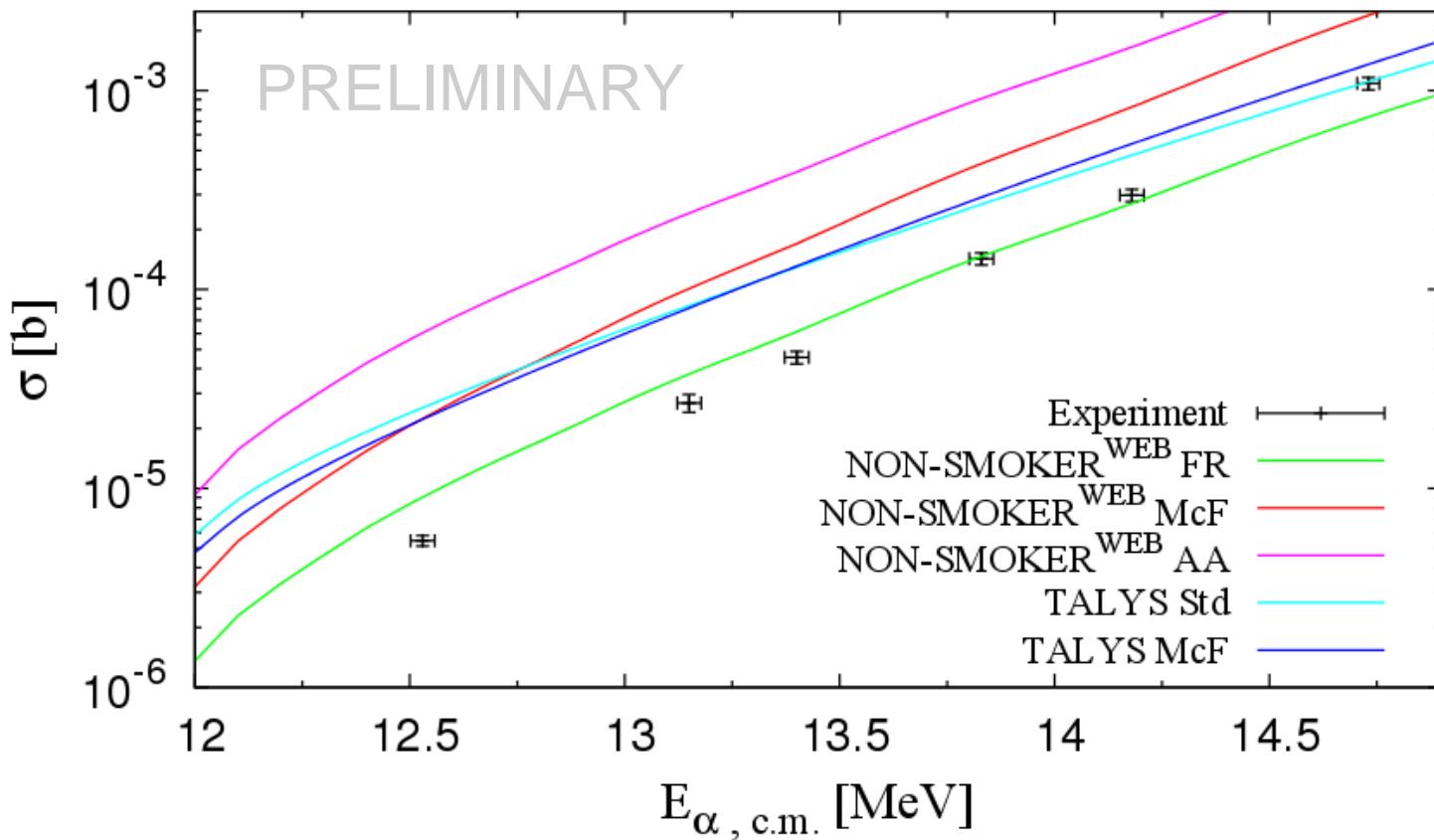
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- no calculation reproduces energy dependence correctly
- overprediction of cross sections up to one order of magnitude

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Summary & Outlook

- counting setup used for determination of small cross sections
 - coincidence technique
 - advantages of digital data acquisition
- addback algorithm to improve peak-to-background ratio

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- influence of γ -strength function, nuclear level density and n-OMP

Counting Setup for Activation Measurements in Nuclear Astrophysics



V. Derya, M. Elvers, J. Endres, A. Hennig,
J. Mayer, S. Pascu, S. Pickstone,
A. Sauerwein, F. Schlüter, M. Spieker,
K.-O. Zell, and A. Zilges

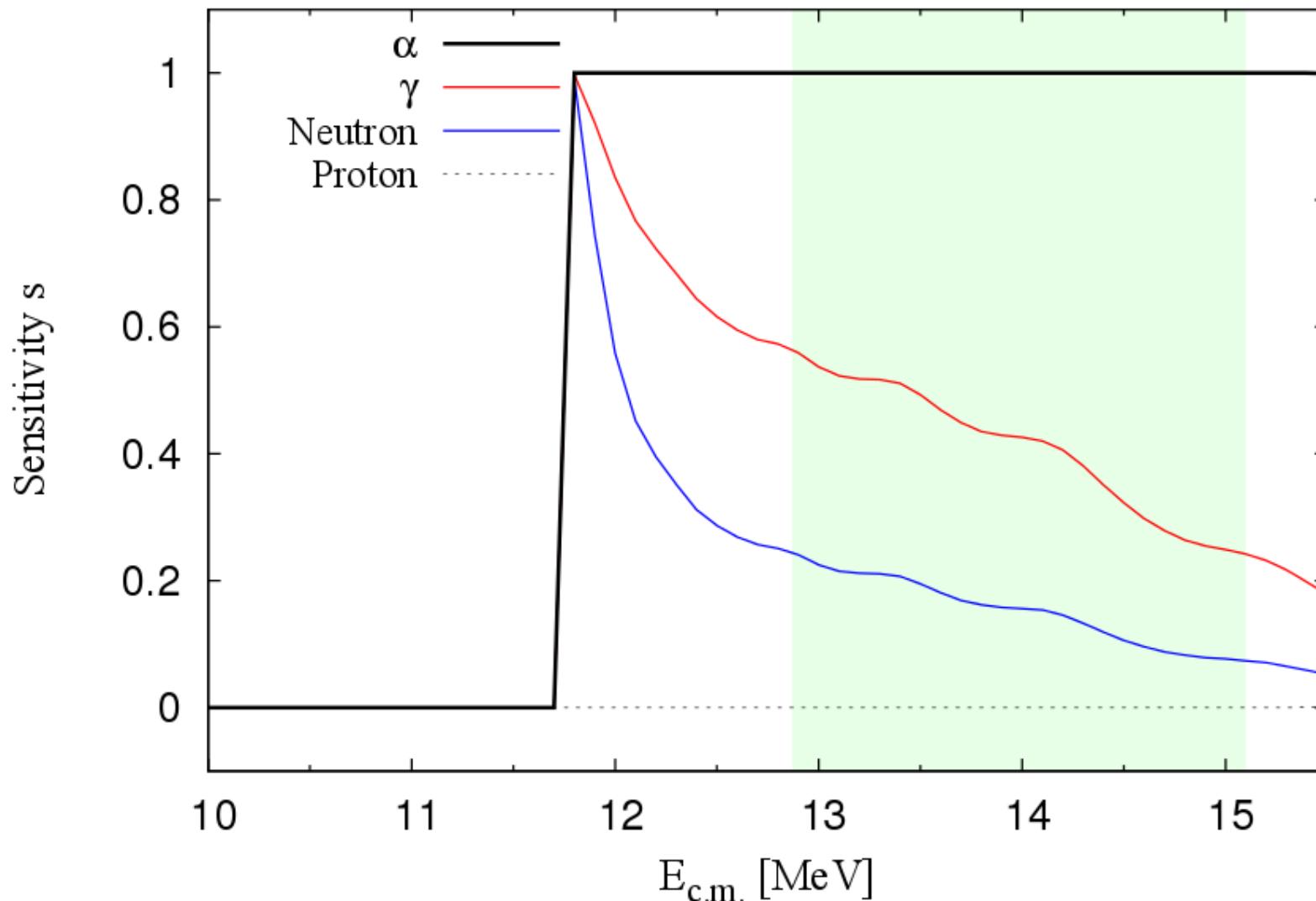


H.W. Becker and D. Rogalla

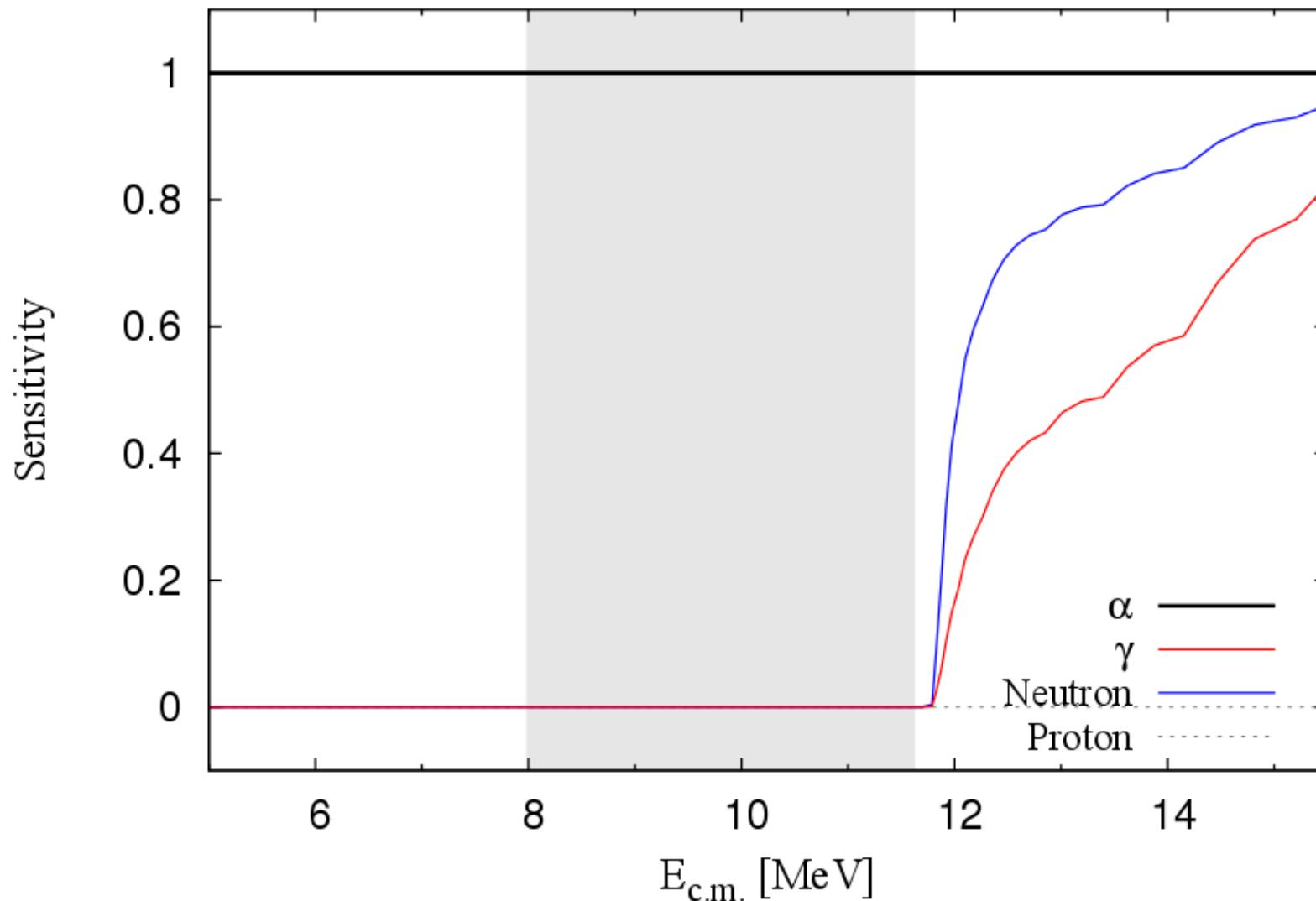


U. Giesen

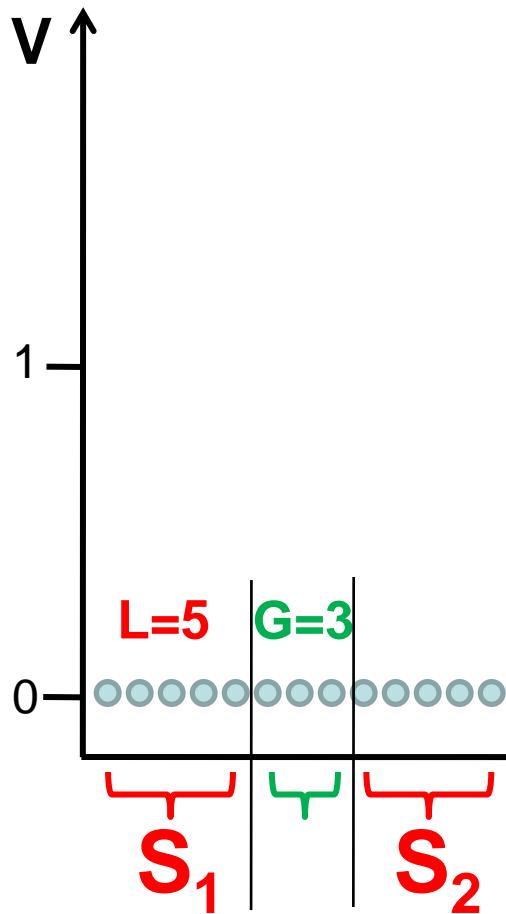
$^{168}\text{Yb}(\alpha, \text{n})^{171}\text{Hf}$ - Sensitivity



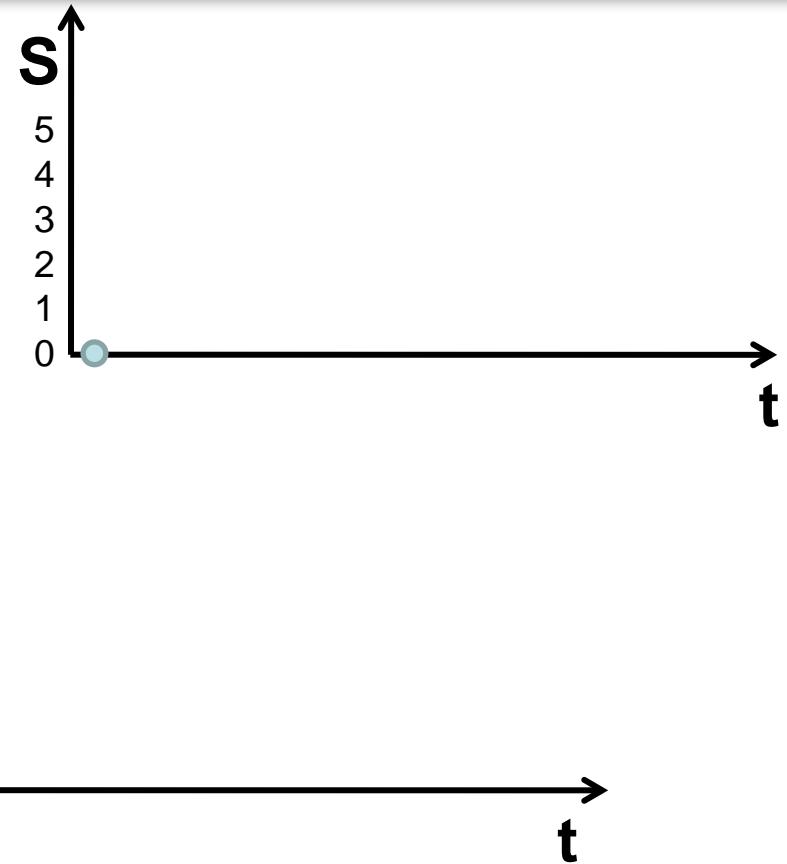
$^{168}\text{Yb}(\alpha,\gamma)^{171}\text{Hf}$ - Sensitivity



Trapezoidal filter algorithm

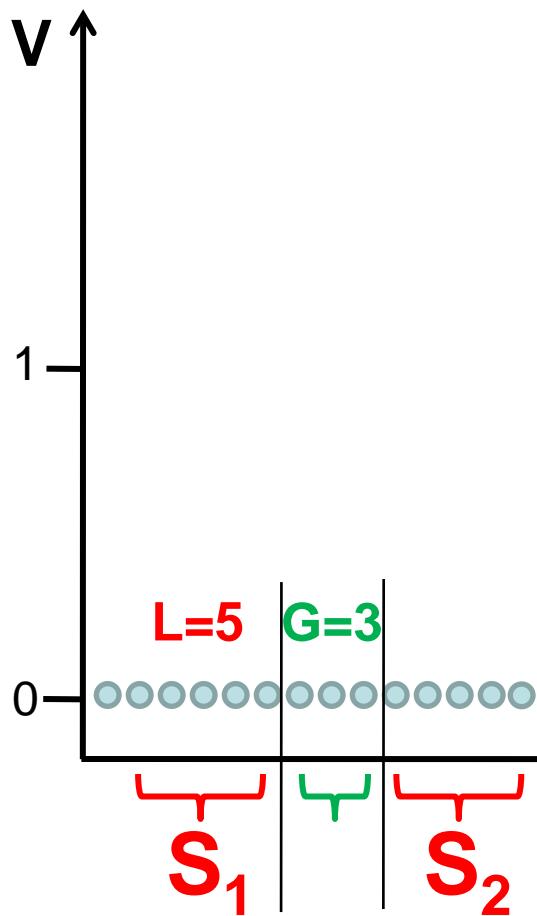


$$S = S_2 - S_1 = 0$$

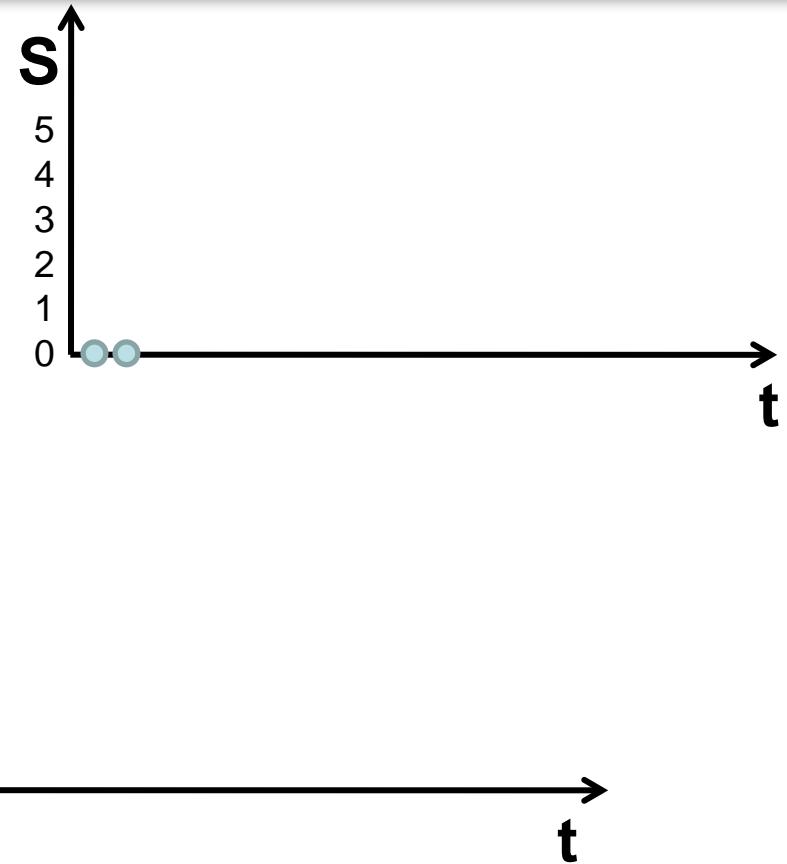


$$LV_{x,k} = - \sum_{i=k-2L-G+1}^{k-L-G} V_i + \sum_{i=k-L+1}^k V_i$$

Trapezoidal filter algorithm

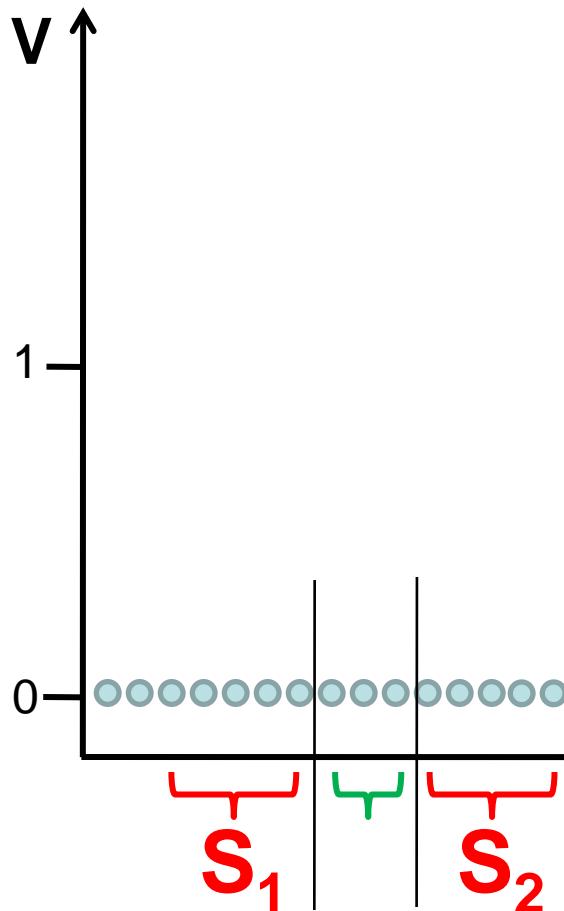


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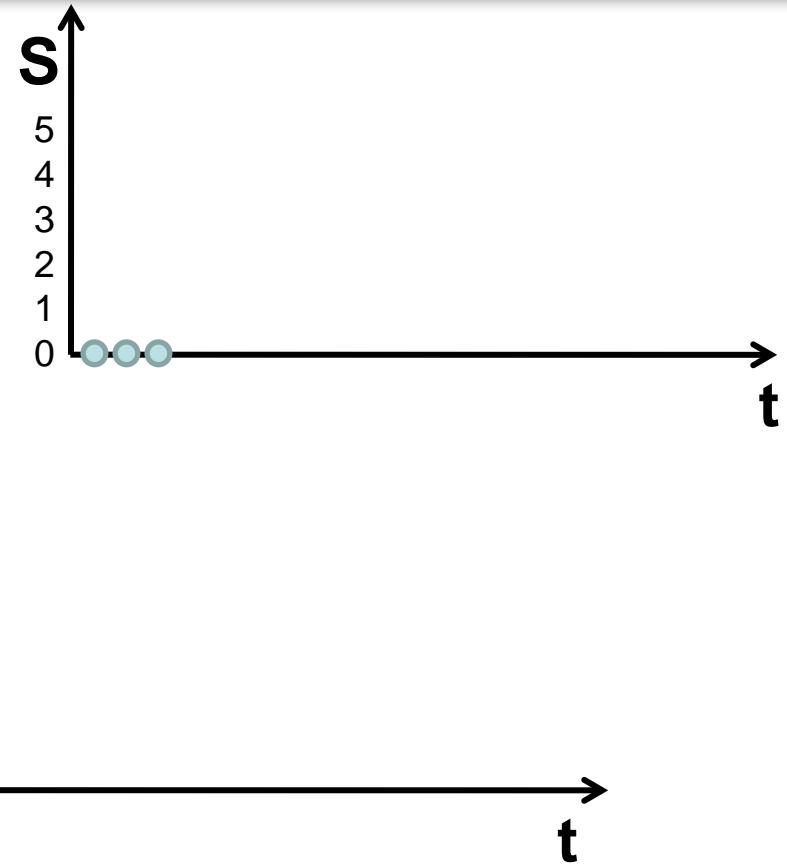


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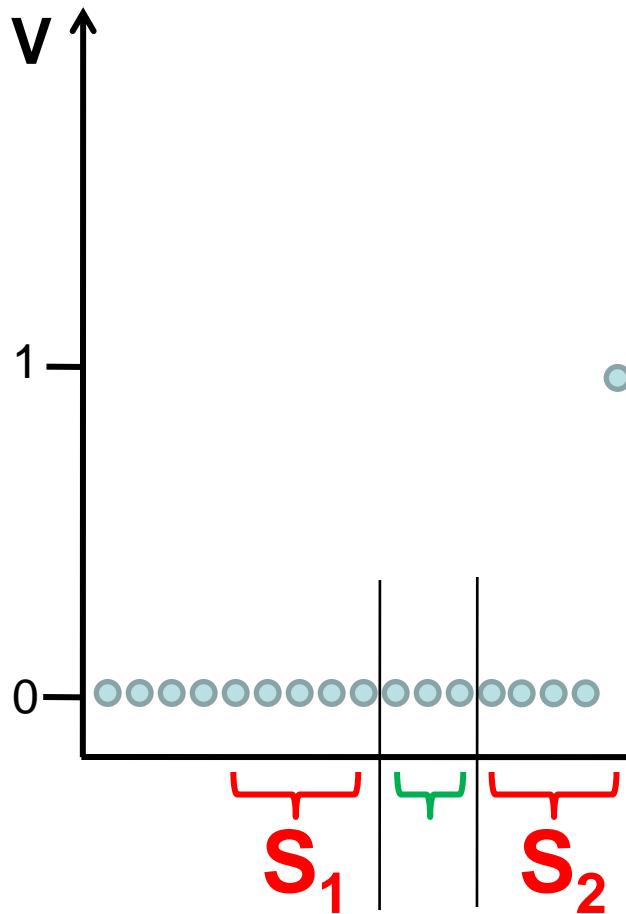


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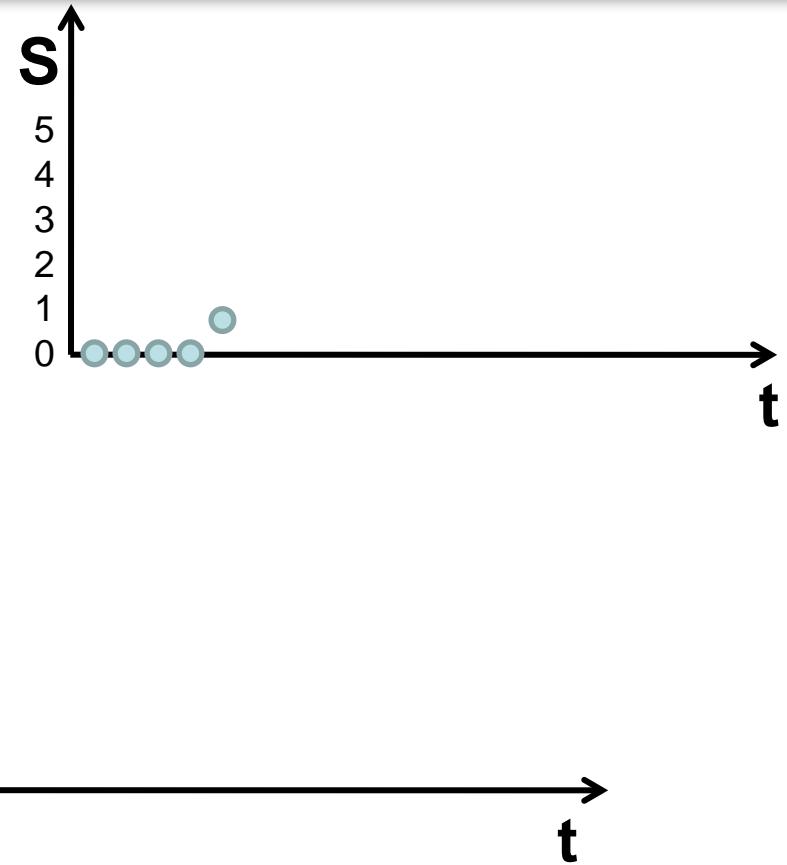


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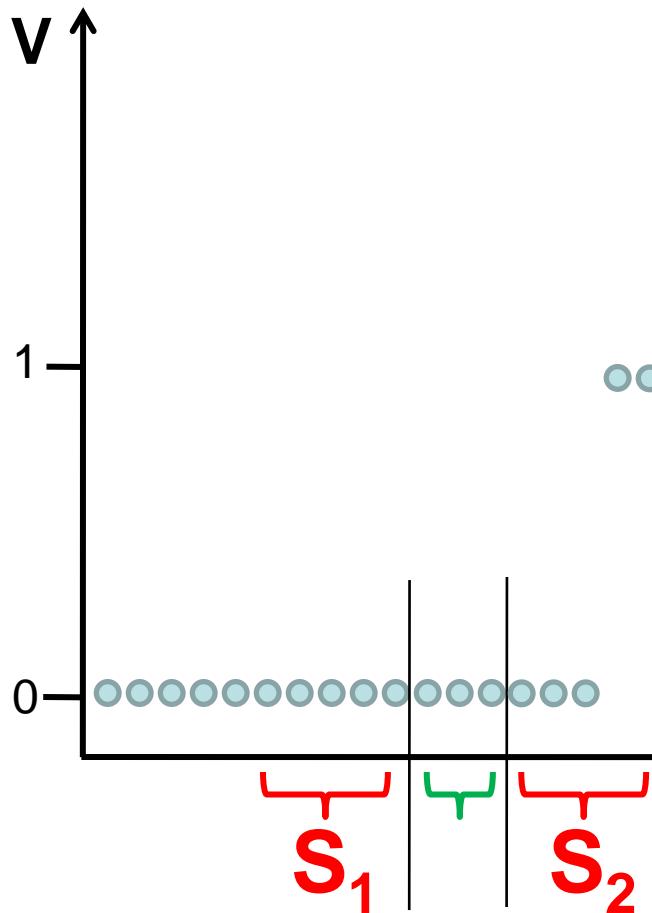


$$S = S_2 - S_1 = 1$$

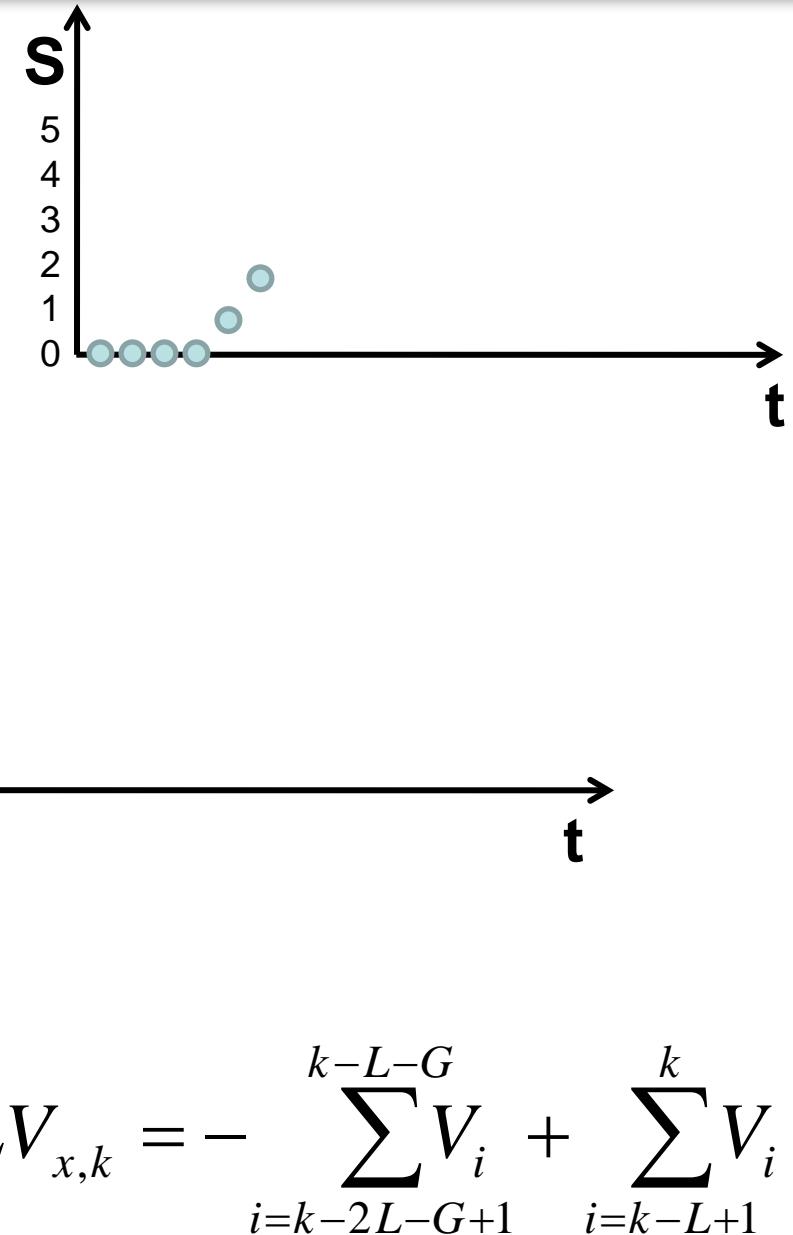


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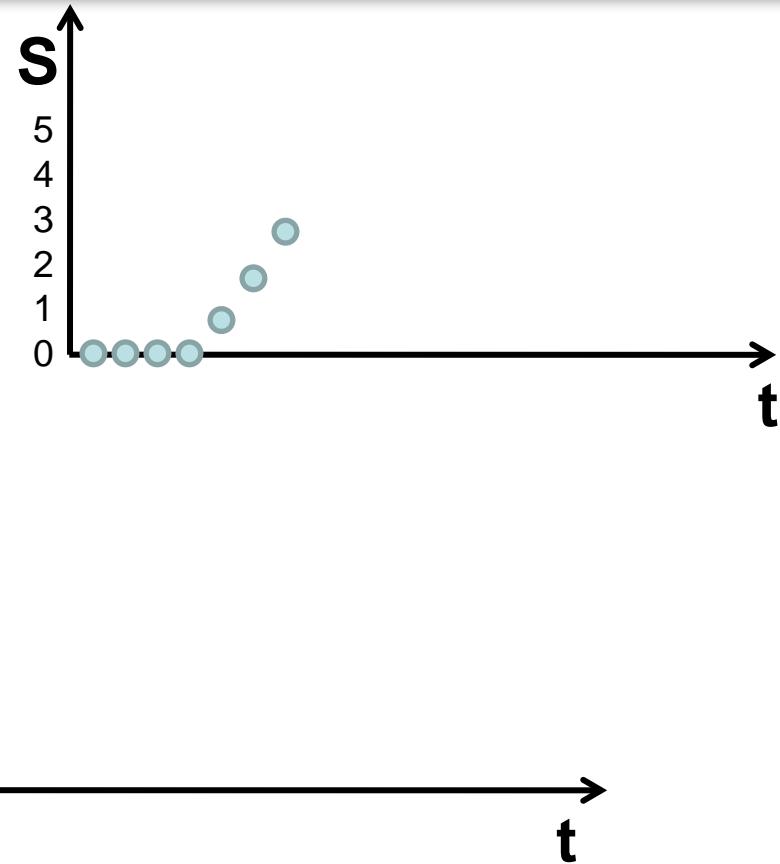
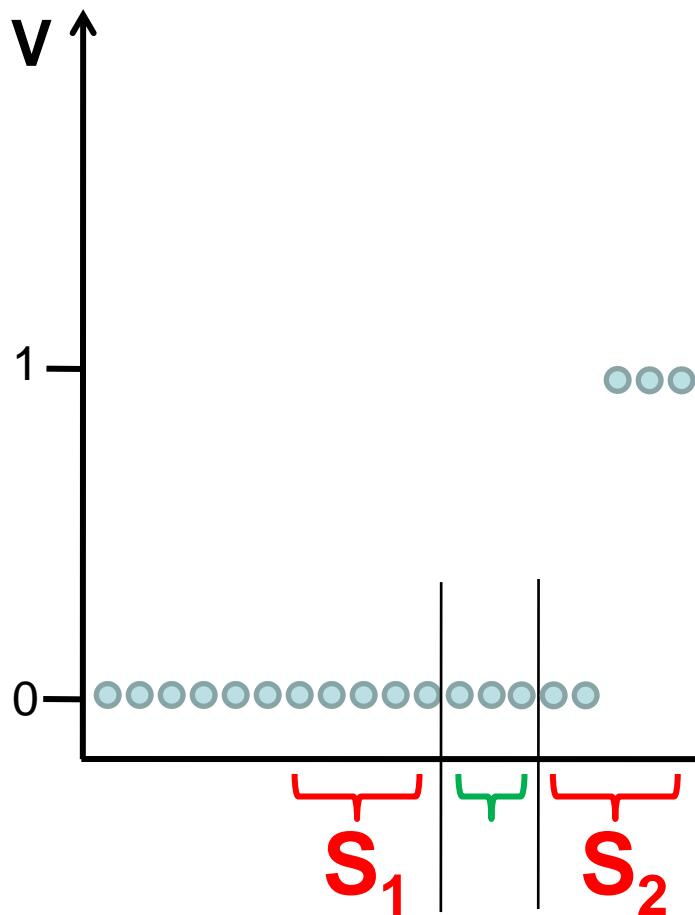


$$S = S_2 - S_1 = 2$$



$$LV_{x,k} = - \sum_{i=k-2L-G+1}^{k-L-G} V_i + \sum_{i=k-L+1}^k V_i$$

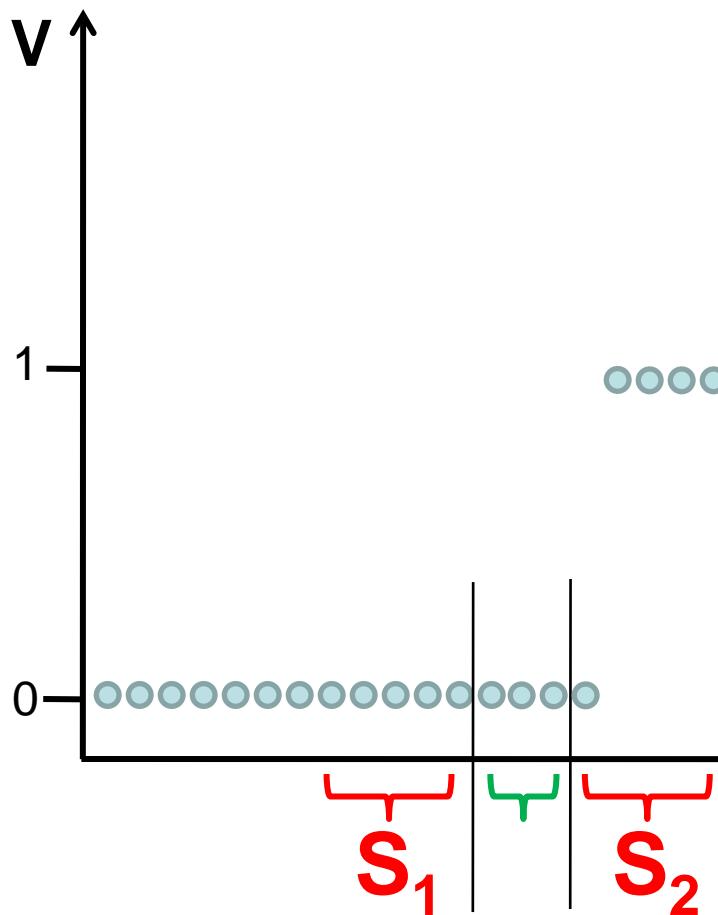
Trapezoidal filter algorithm



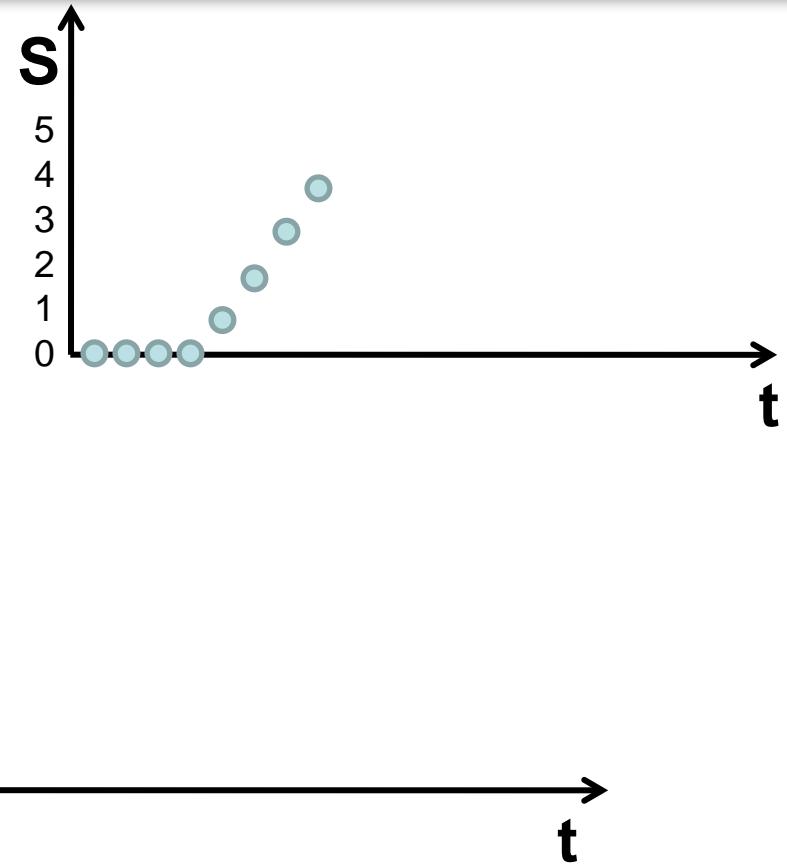
$$S = S_2 - S_1 = 3$$

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Trapezoidal filter algorithm

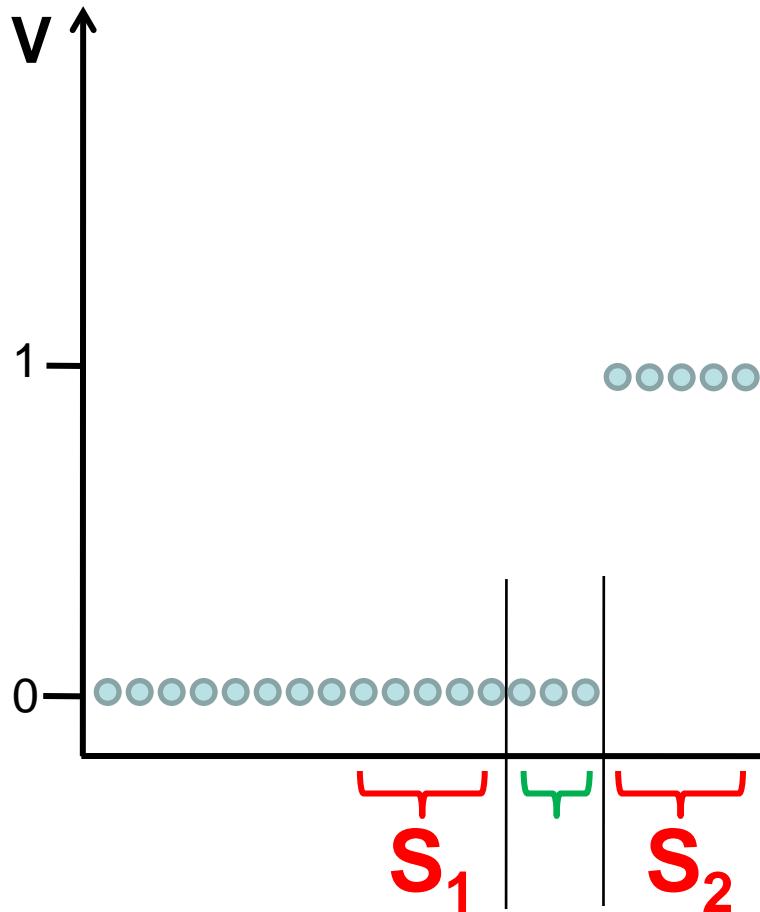


$$S = S_2 - S_1 = 4$$

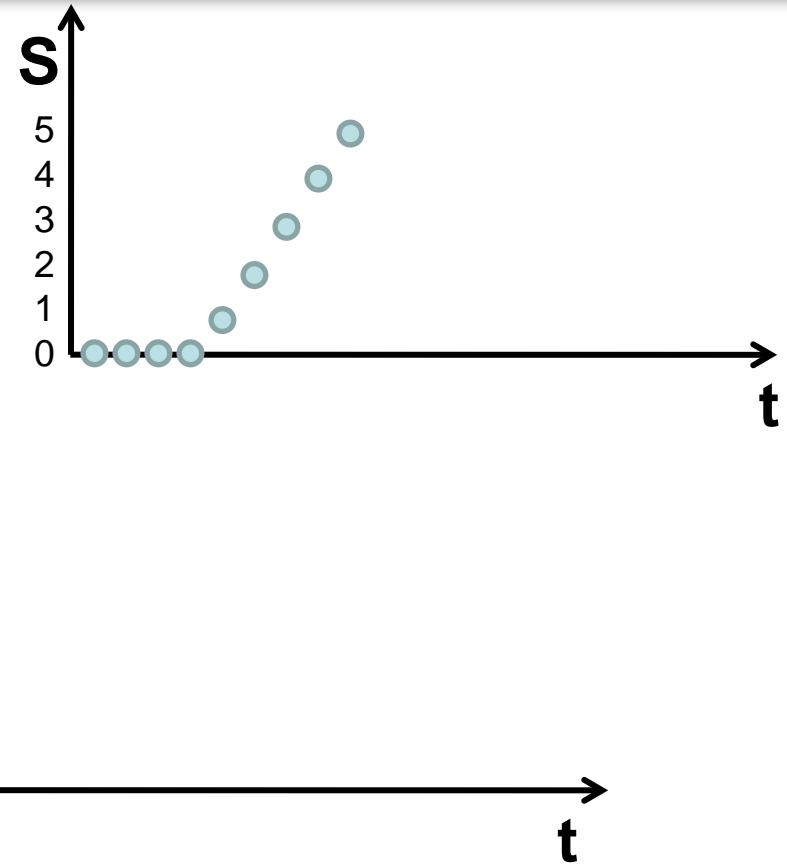


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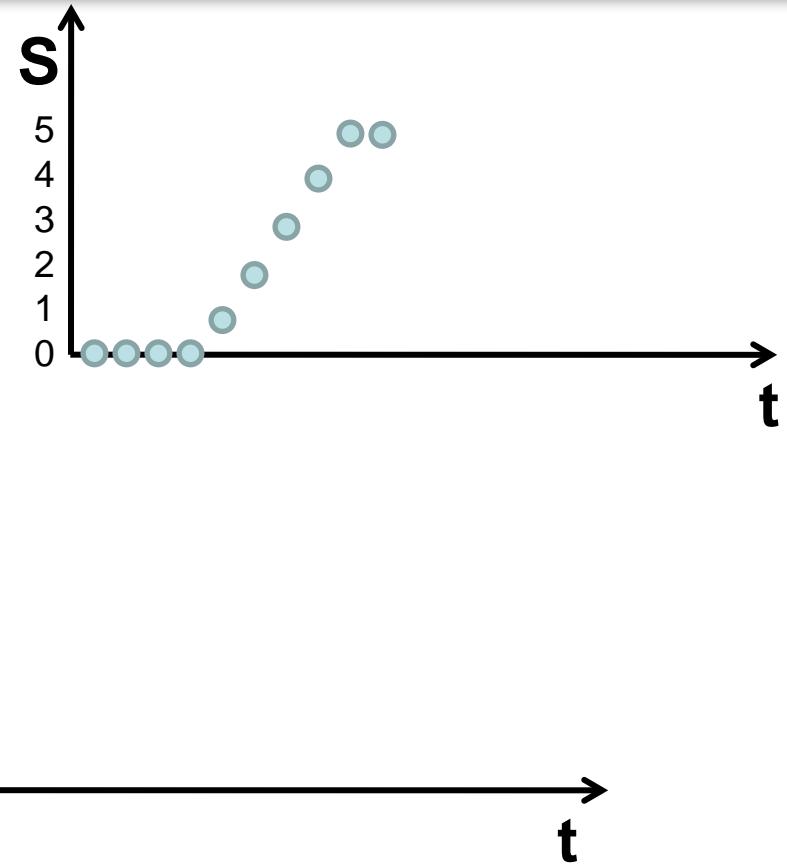
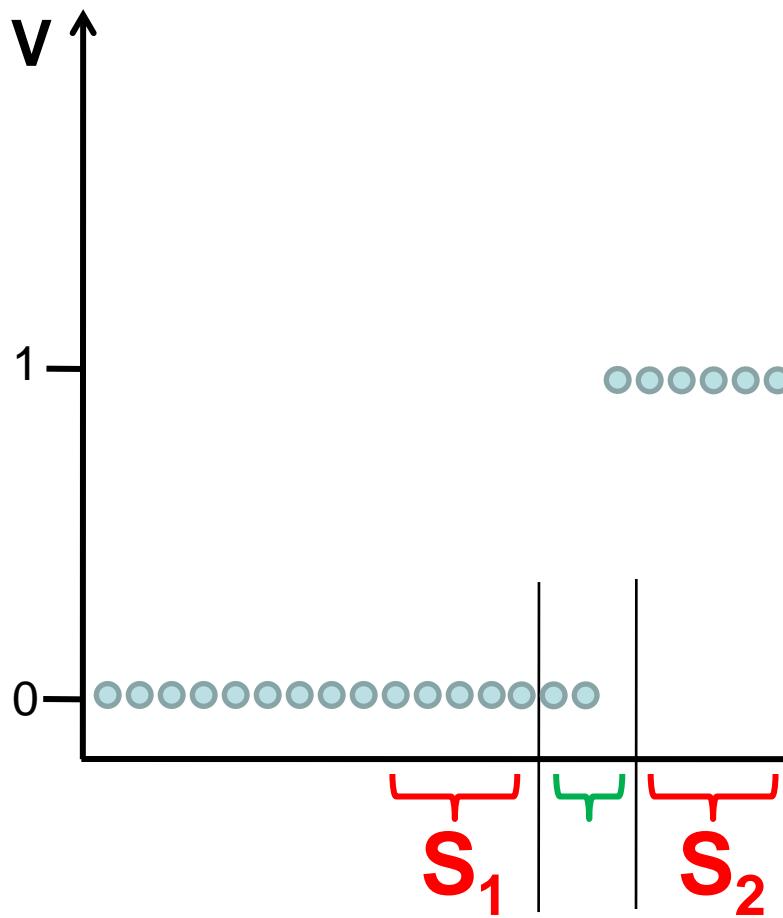


$$S = S_2 - S_1 = 5$$



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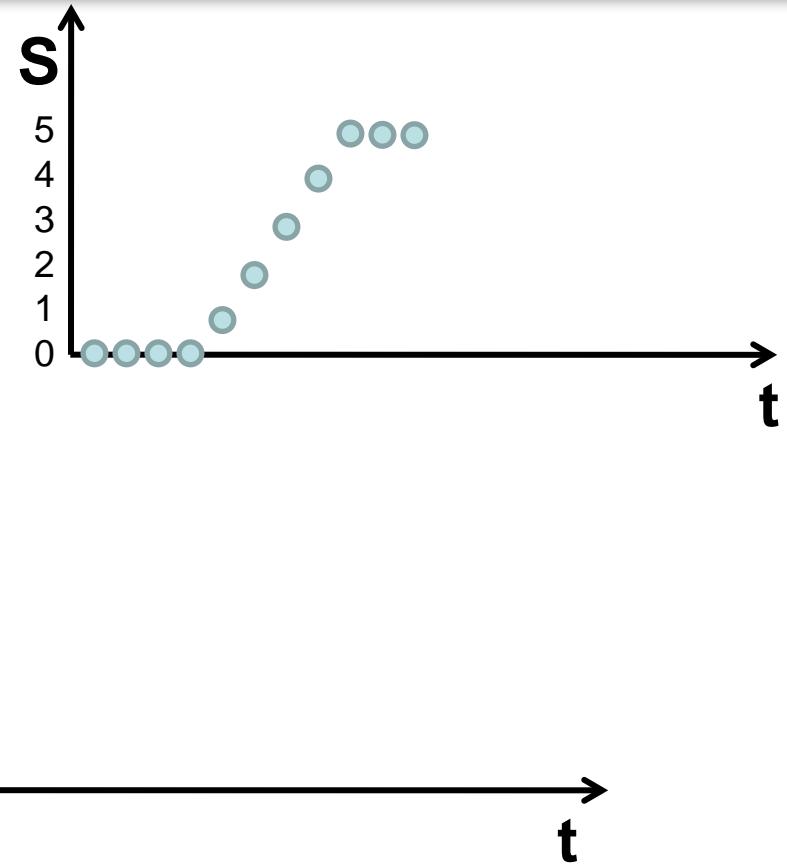
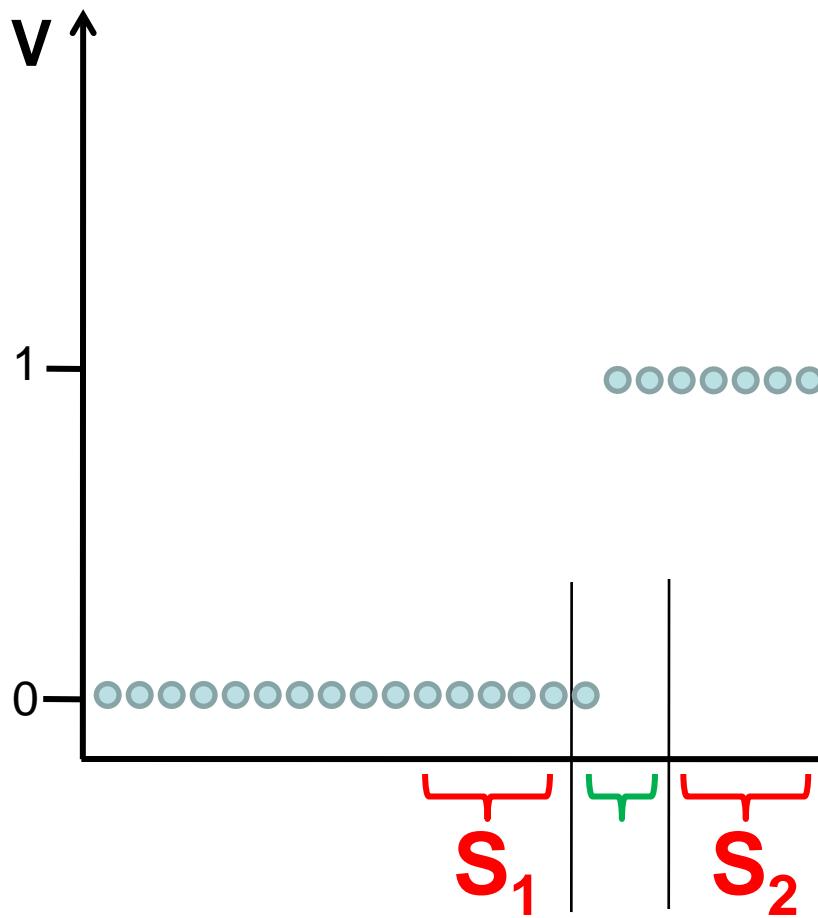
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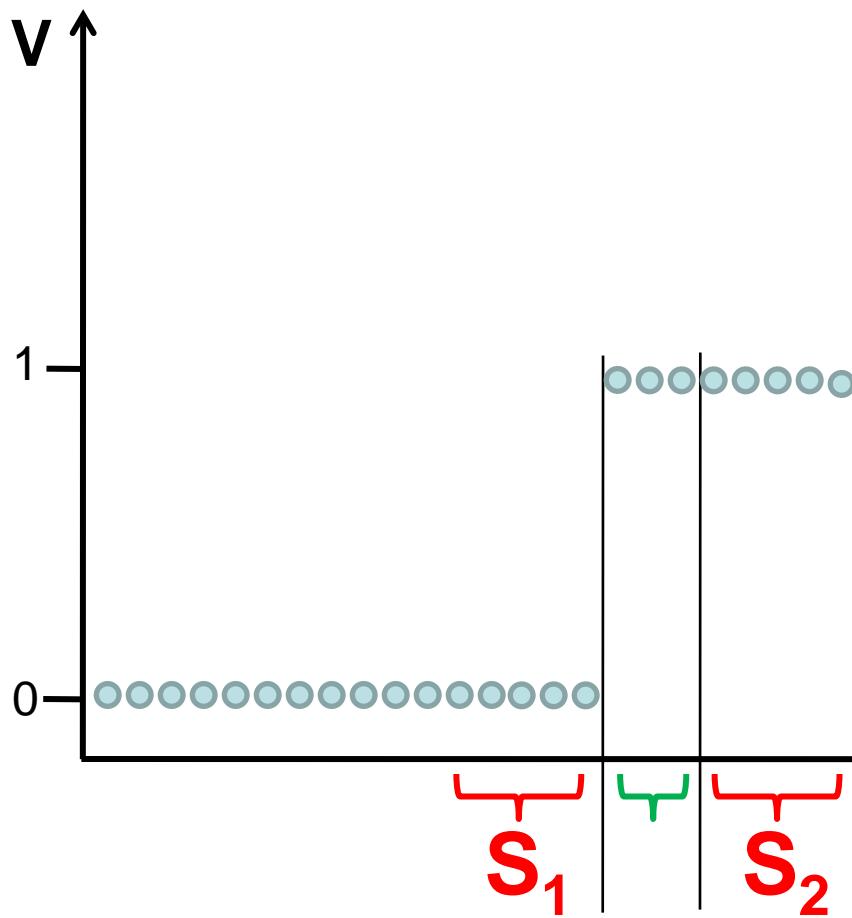
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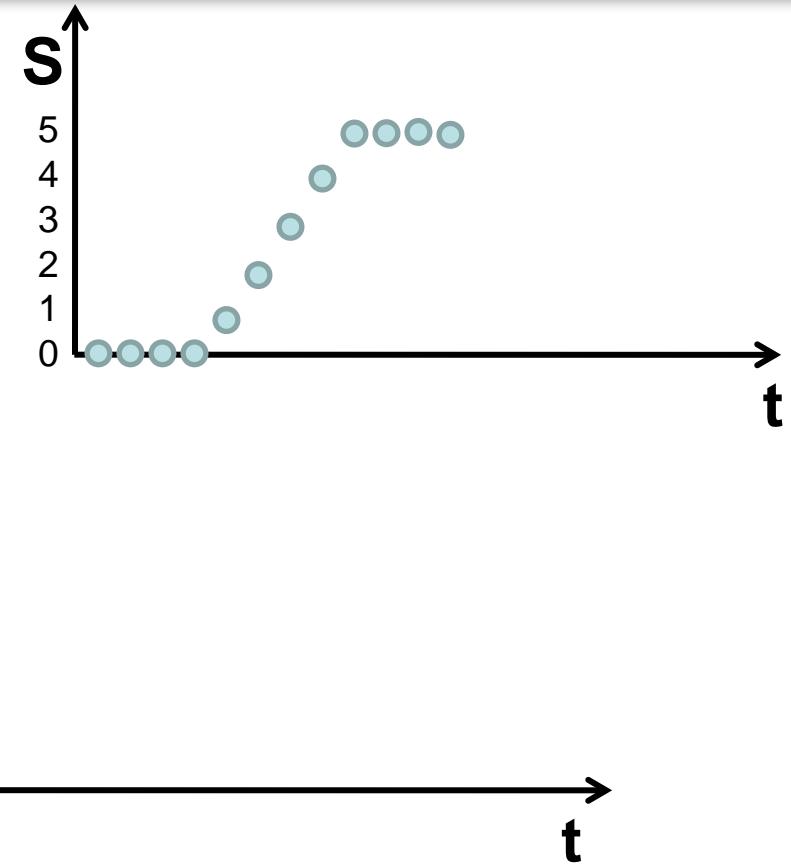
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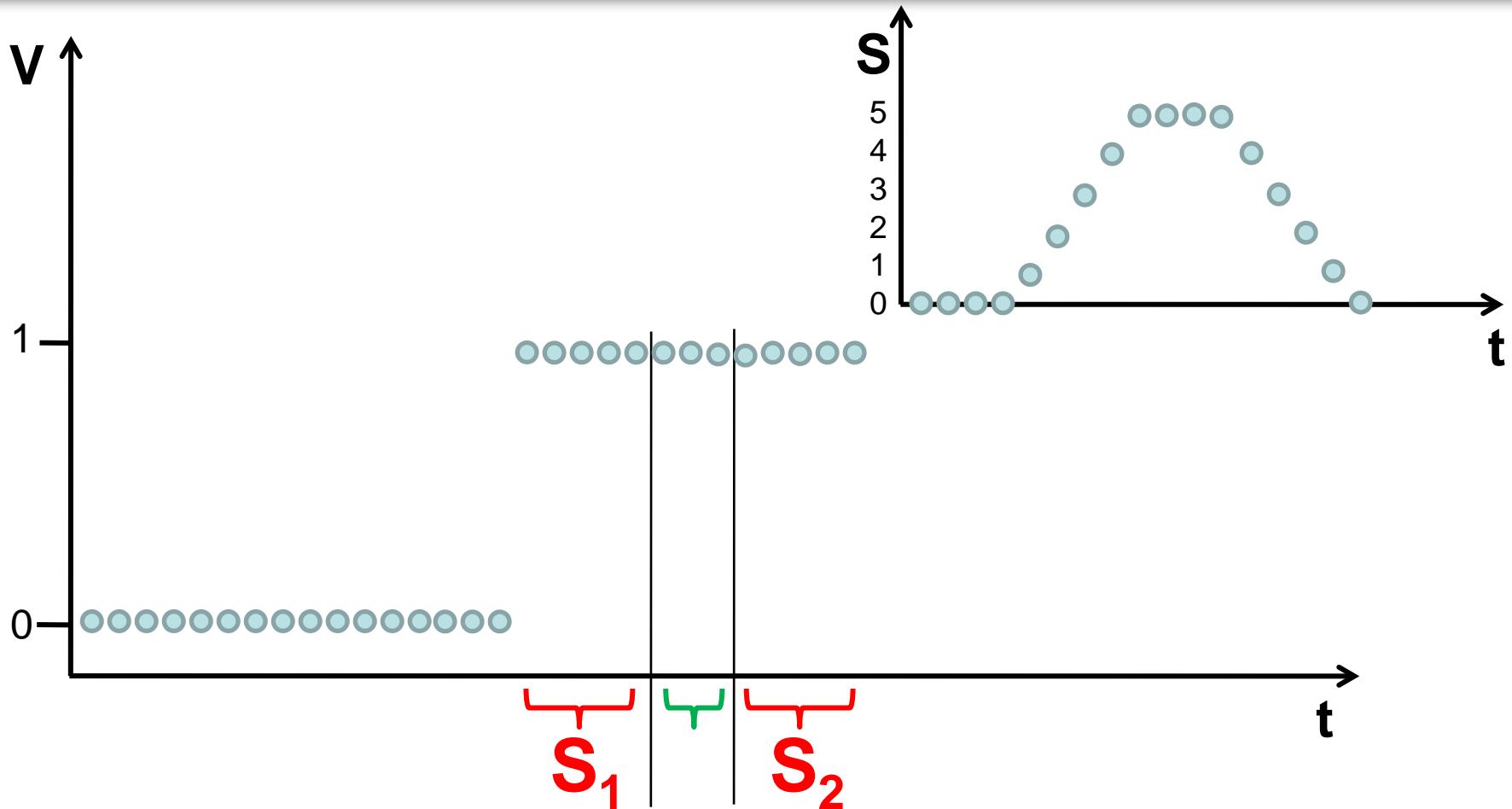


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