# Measurement of $^{24}$Mg(n, n'$\gamma$) at n_TOF, CERN

## IoP Nuclear Physics 2025

24th April

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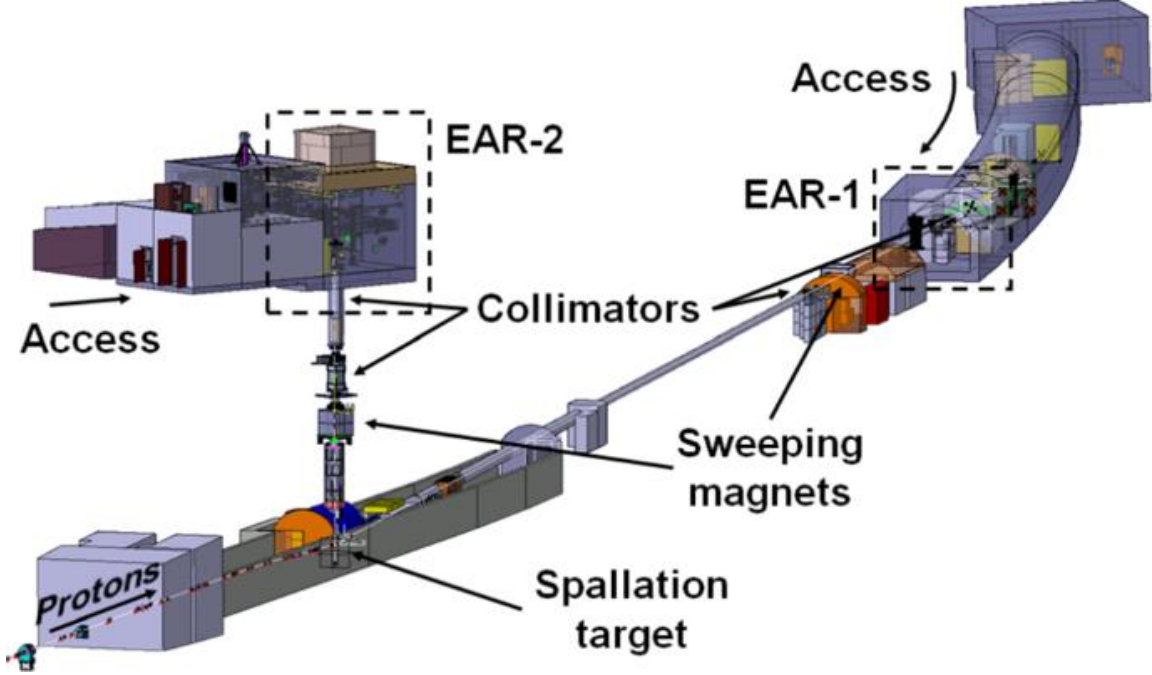
# Brief summary of n_TOF

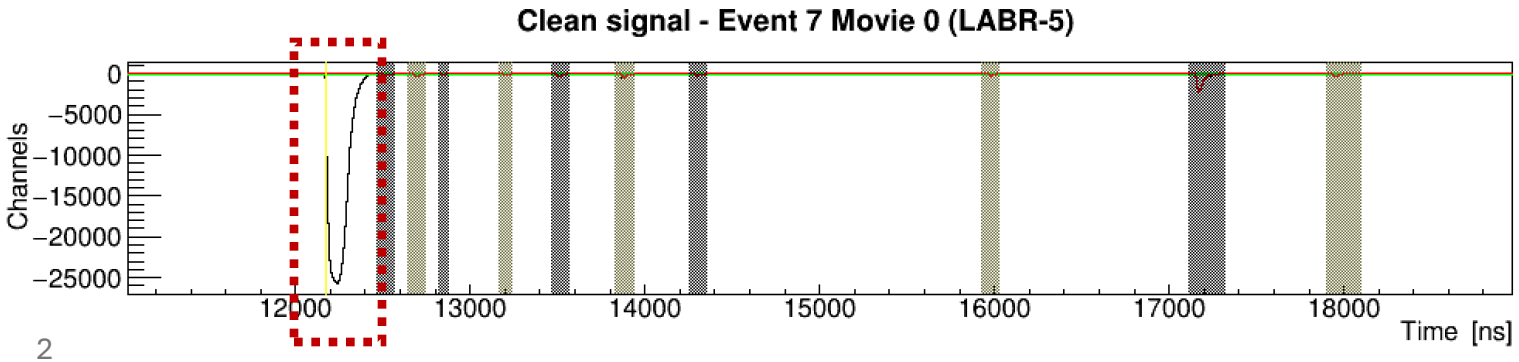



## White neutron source

- Pulsed white neutron source
- Spallation by 20 GeV P+ on lead target
- ToF technique to calibrate neutron energies

## Two Primary Experimental Areas

- EAR1 – 184 m flight path – Good ToF resolution
- EAR2 – 20 m flight path – Stronger flux



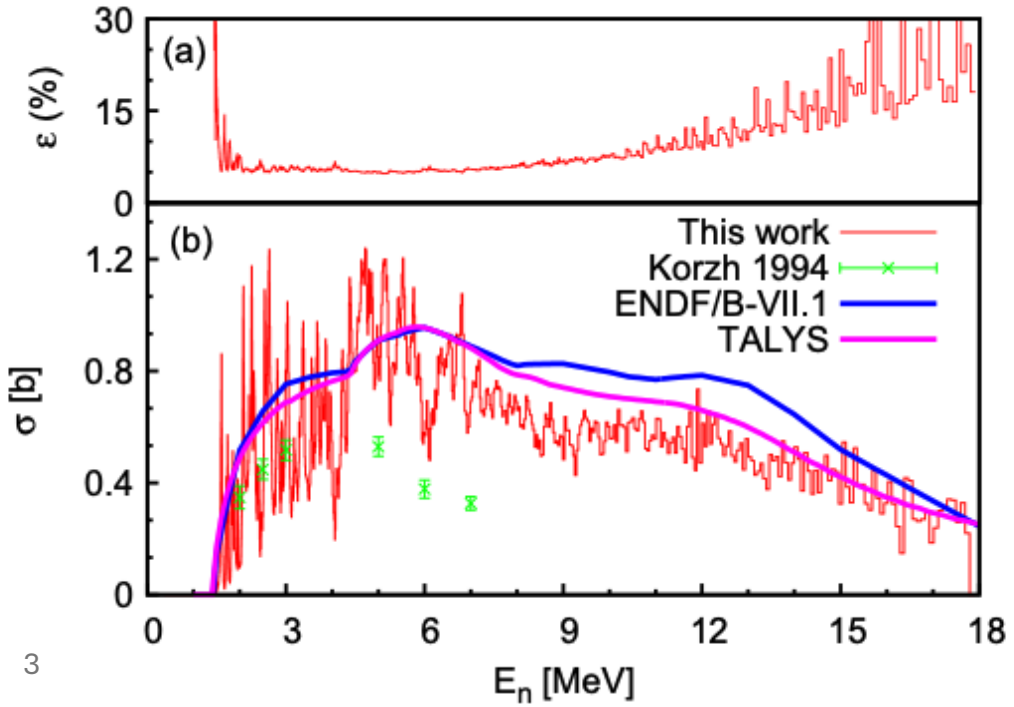

## "$\gamma$ – Flash"

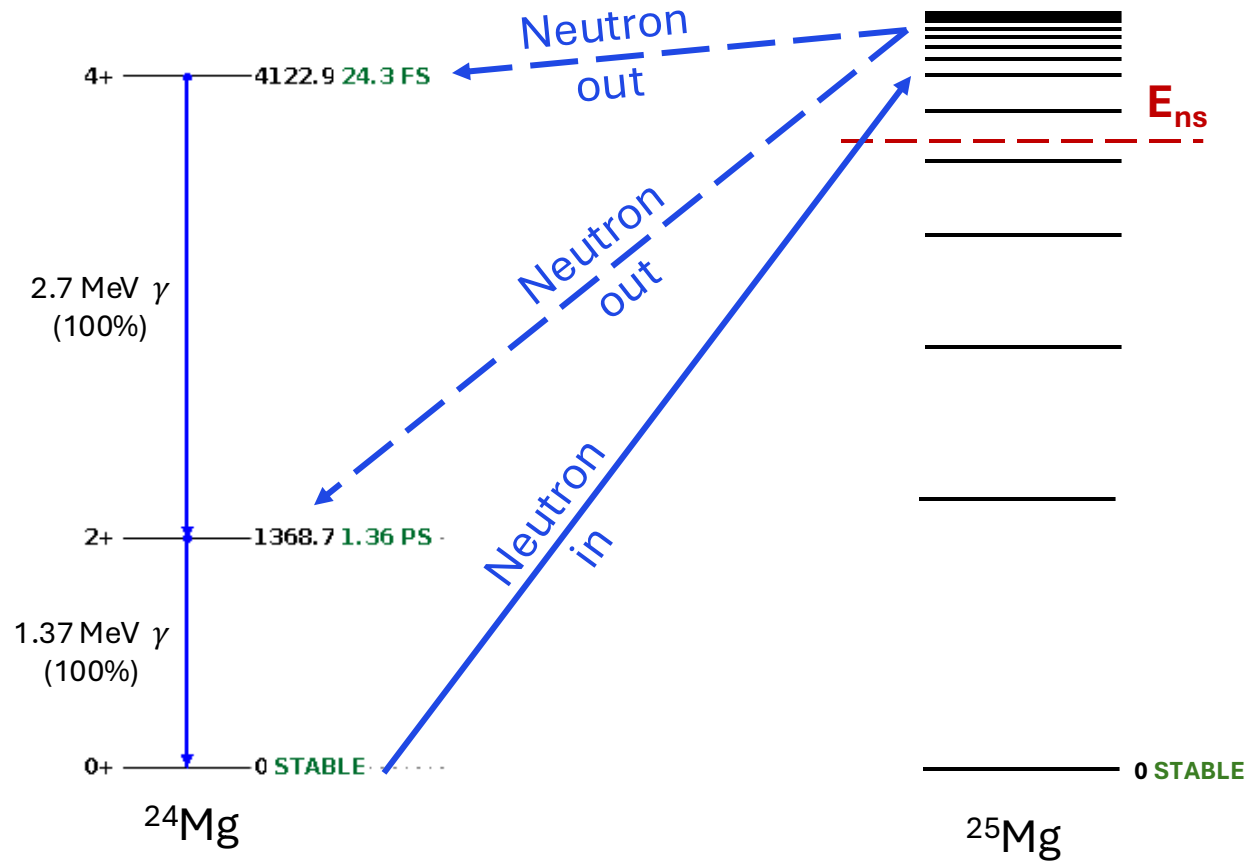
- Intense surge blinds detectors
- Variable – must wait for detector recovery
- Similar in EAR1/2, but EAR2 much closer

# Motivation – $^{24}$Mg

## Relevant isotope

- Proposed as component of fuel for some Gen IV designs as a moderator.
- Medical (moderator in Boron Neutron Capture Therapy)



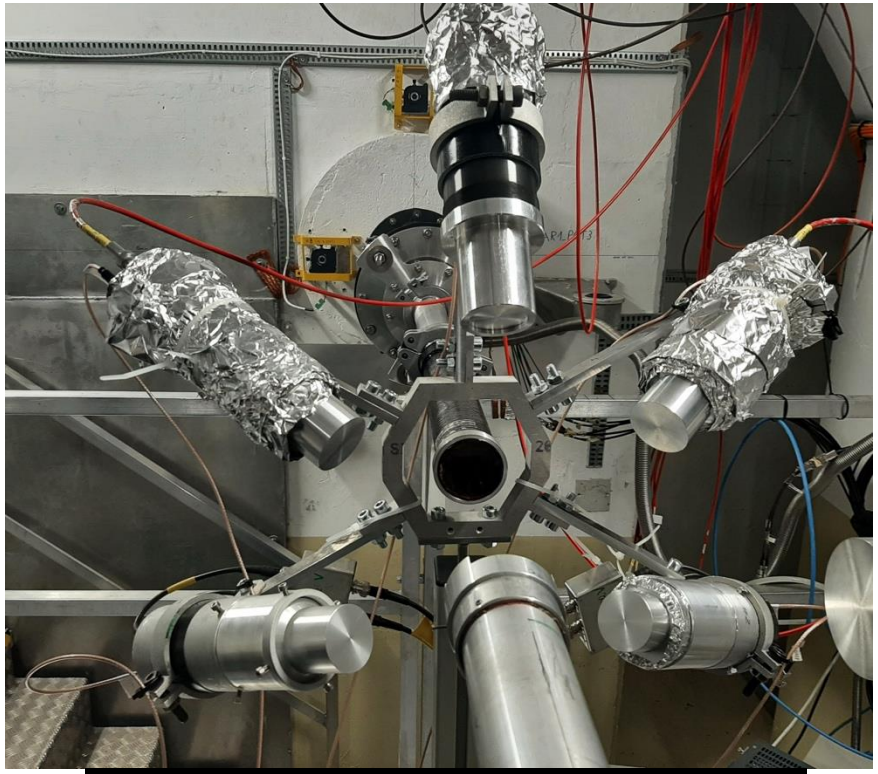




## A good facility benchmark

- Measurements at GELINA for comparison (A. Olacel et al., 2014) (GAINS)
- Main gamma above background and neutron sensitivity (from $^{79}$Br, $^{81}$Br, $^{139}$La, $^{19}$F)
- Simple level scheme

# Experimental Set-up

“Spider” detector mount @ EAR 1 capture position.

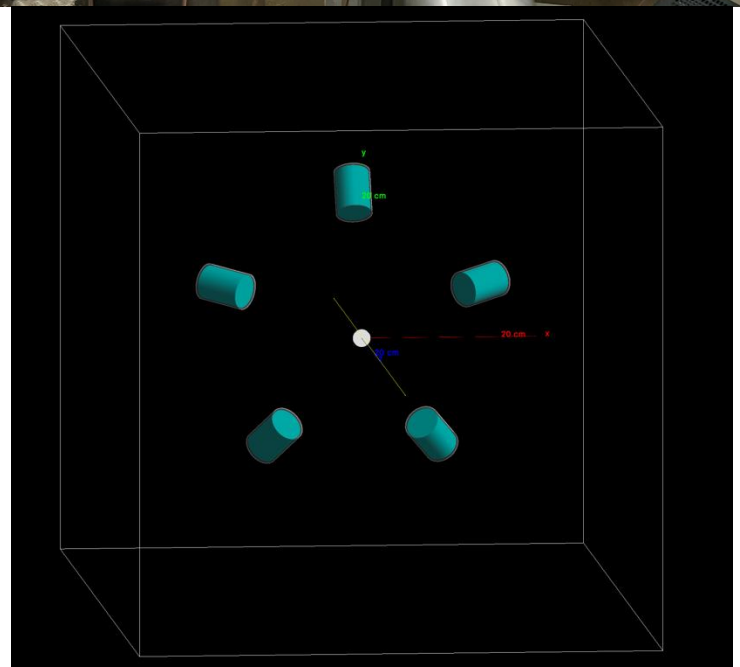


## $^{24}$Mg Sample

- Enriched to 98.5% from 80%
- 2 cm diameter, 0.8 mm thickness

## Five Lanthanum-Bromide ($LaBr_3$) detectors

- Three of 1.5x1.5” (diam, depth)
- Two of 1.5x2”
- 17 cm and 125 degrees

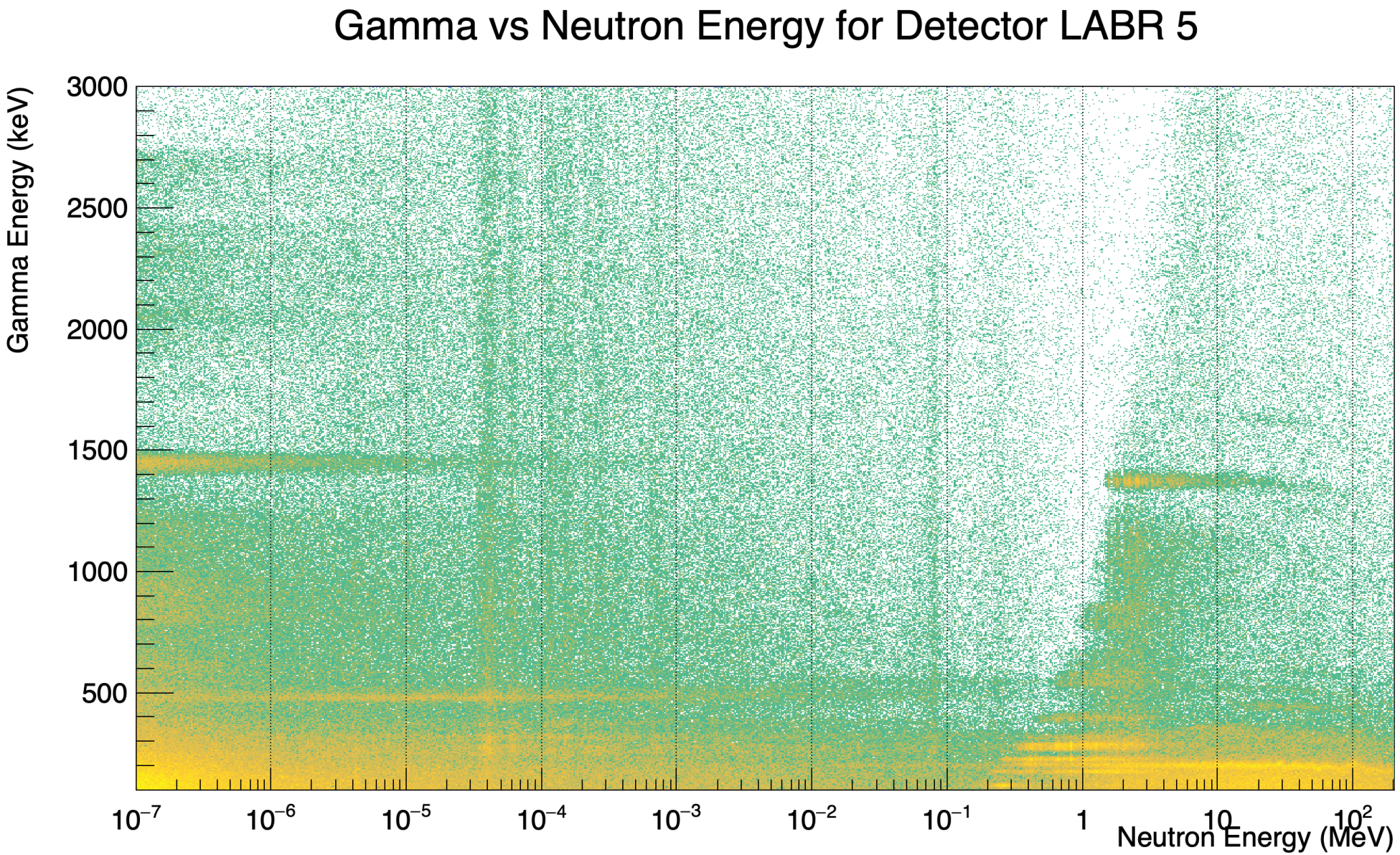


## Total campaign was ~8 days

- ~2 days for finalising configuration.
- ~6 days of stable beam time.

# Example of collected data

**Data from 6 days (7.5e17 Protons)**



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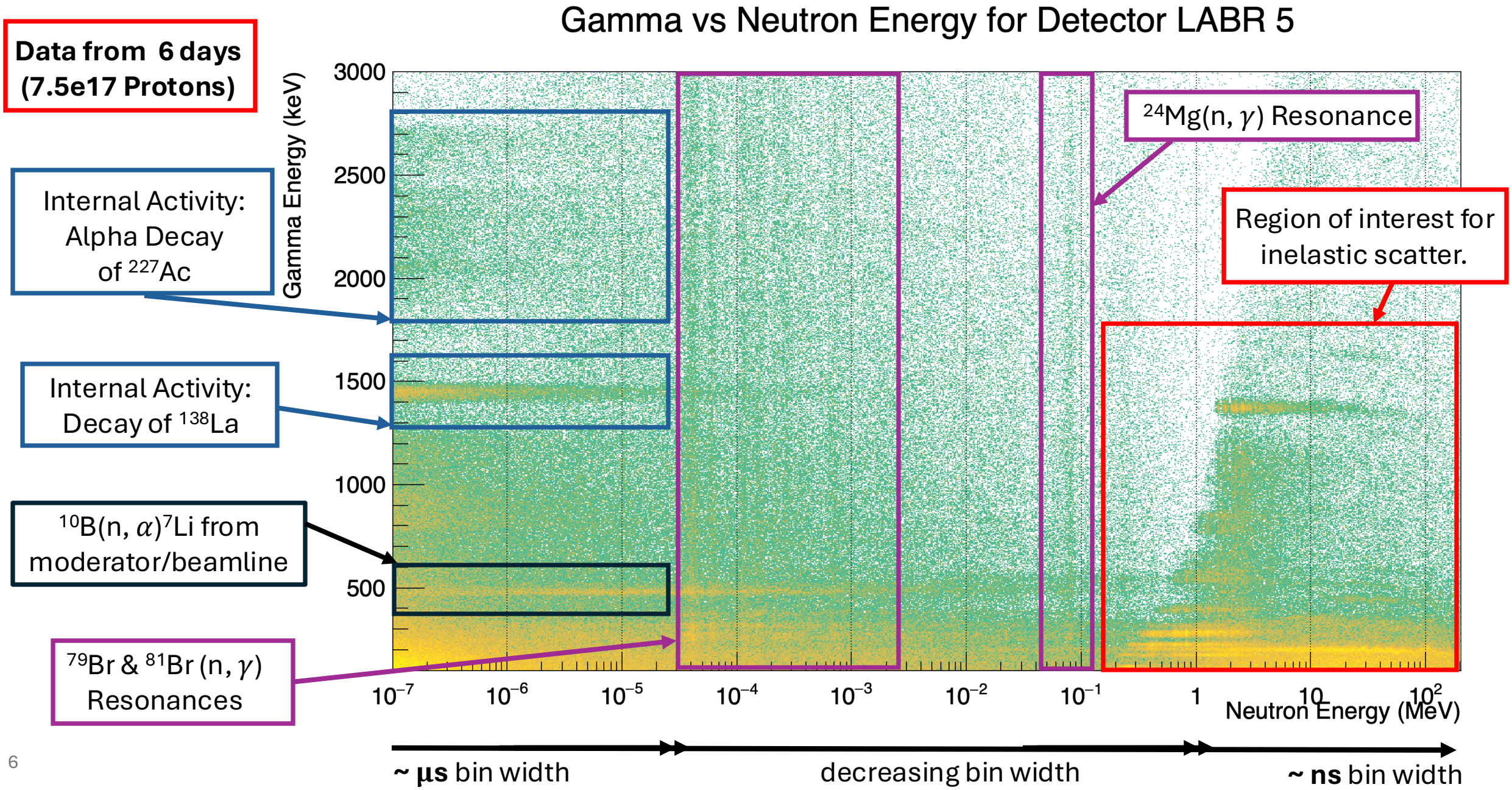
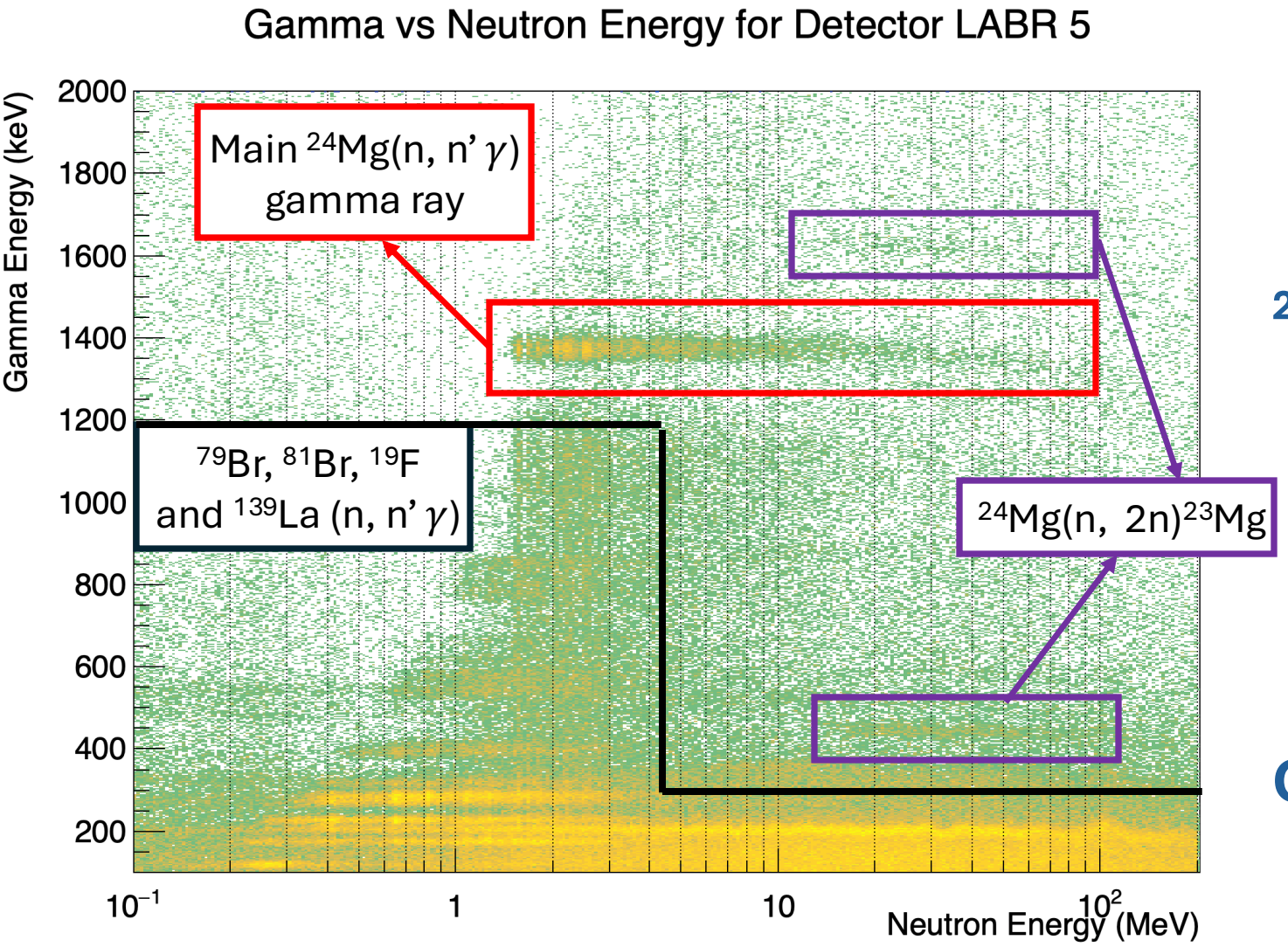


# RoI - Features




## Gain drift and Ringing

- poses an issue beyond ~20-25 MeV neutron energy due to poor stats
- Both XS and Flux drops beyond 10 MeV neutron energy

## $^{24}$Mg(n, 2n)$^{23}$Mg Reactions

- Visible up to 100 MeV neutron Energy (451 keV gamma)
- Problematic - can be indistinguishable from (n, n')

## Gamma Production XS

- Track intensity of gamma as function of neutron energy

# Cross Section Calculation

$$\sigma = \frac{R}{\phi\, n}$$

$R$ - Reaction rate

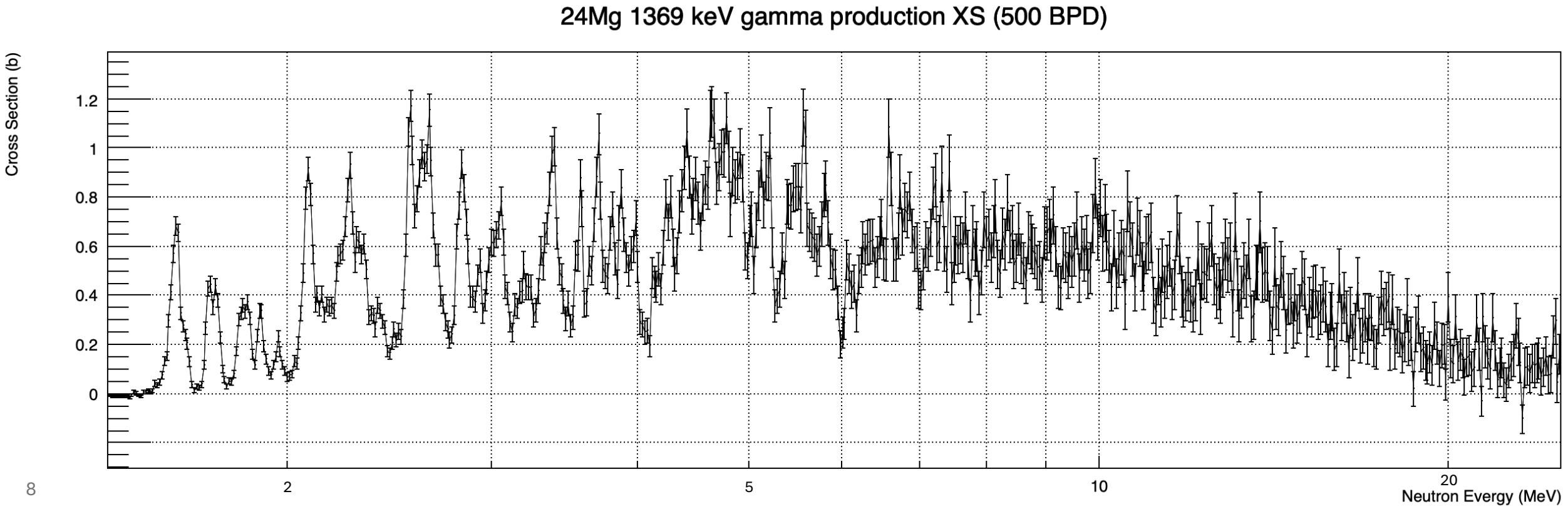
$\phi$ - Incoming particle flux

$n$ - Atomic areal density

$R$ - from measurement

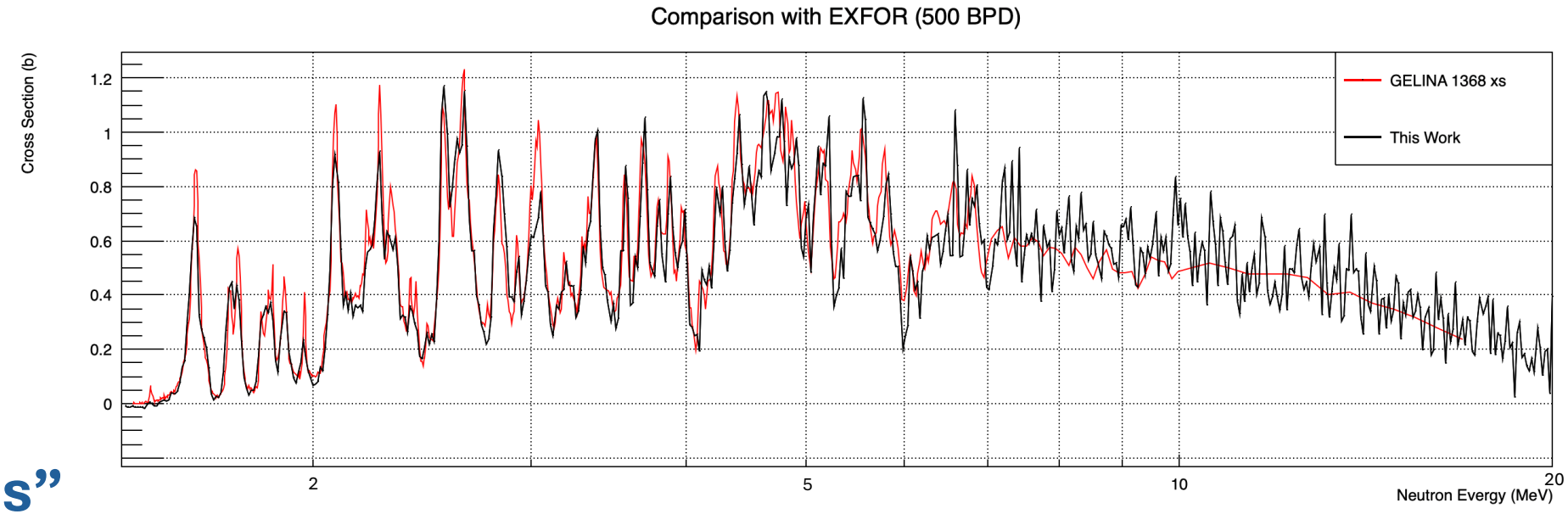
$\phi$ - from evaluated n_TOF flux

$n$ - sample specific – easy to measure



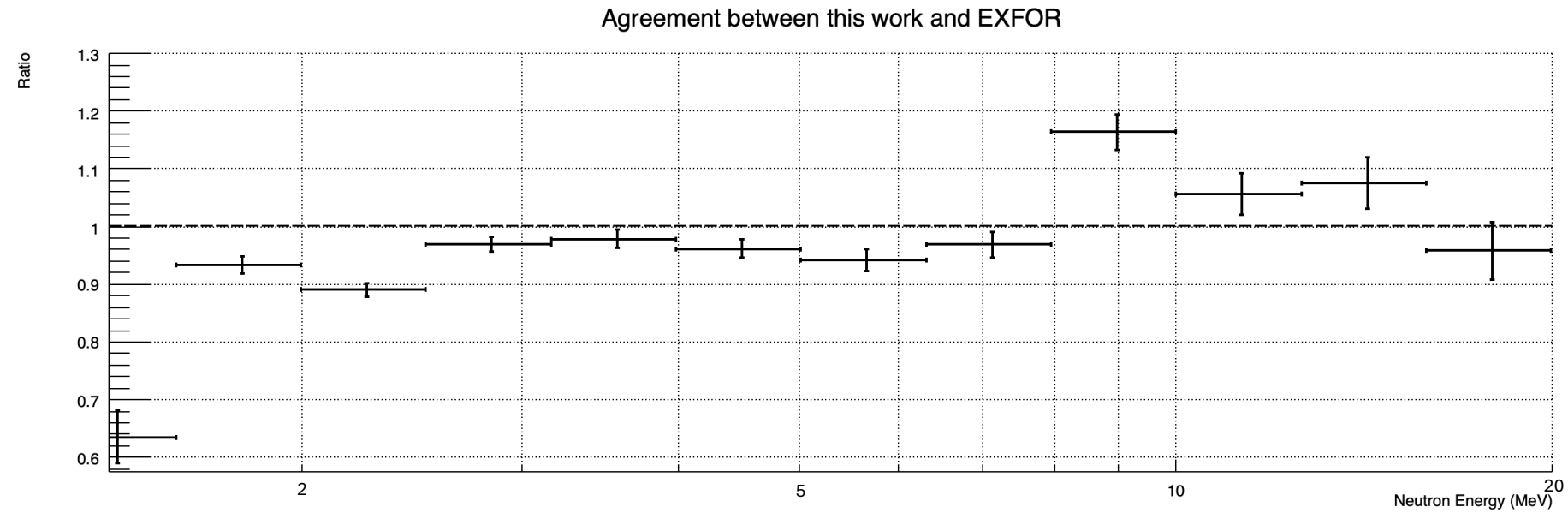
# Comparison to EXFOR

**Generally, very good agreement and demonstrates the suitability of n_TOF**




## Weaker "Resonances"

- Resolution function
- Binning




## Upper Limit

- flux allows for higher energies
- $\gamma$ - flash not an issue

# Conclusion and the future

**Demonstrated the capability of n_TOF for this measurement type.**

## Further Proposals

- $^{19}$F and $^{28}$Si (n, n'$\gamma$) measurements accepted for beam time later this year
- $LaBr_3$ detectors being considered for other n_TOF measurements

## Building an array

- Large order placed for 1.5x2" / 2x2" $LaBr_3$ detectors
- Improve statistics and analysis

## A part of n_TOF's physics programme going forward.

# Thank you for listening

# Analysis

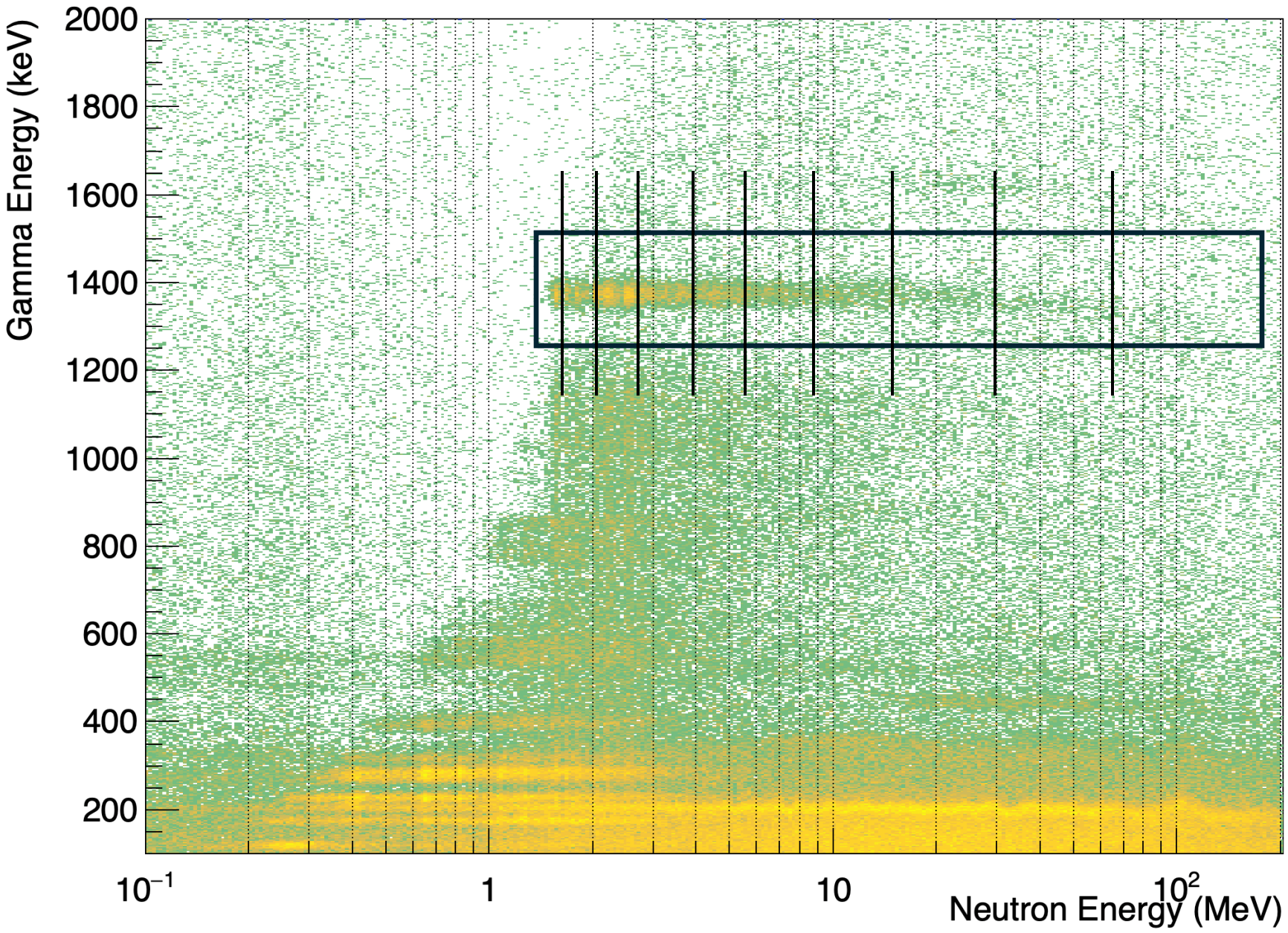
Track gamma intensity as function of Time-of-Flight ($E_n$).

**Fine $E_n$ bins**

- Better Resolution
- Not necessary at low ToF

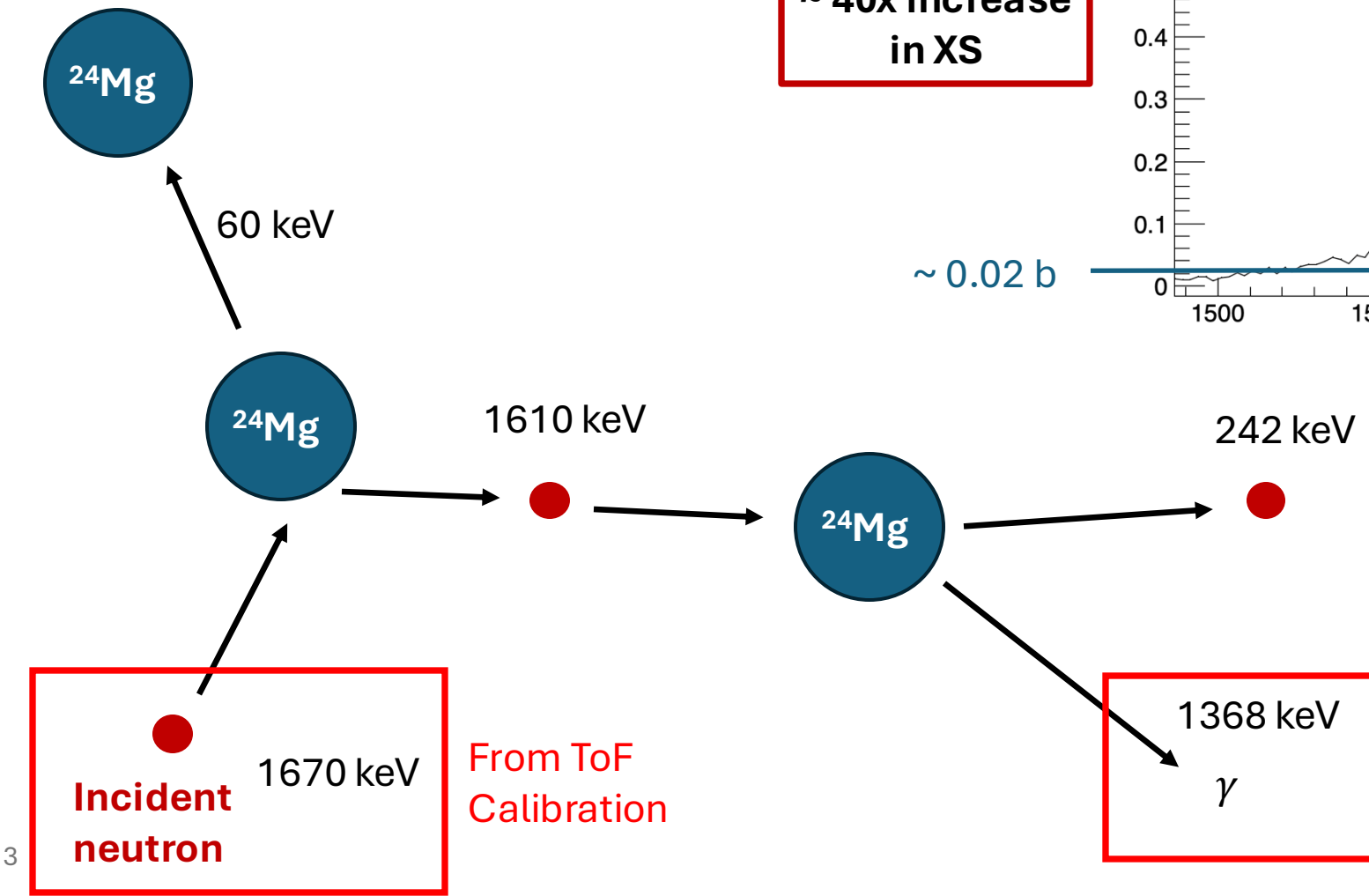
**Apply gaussian fits**

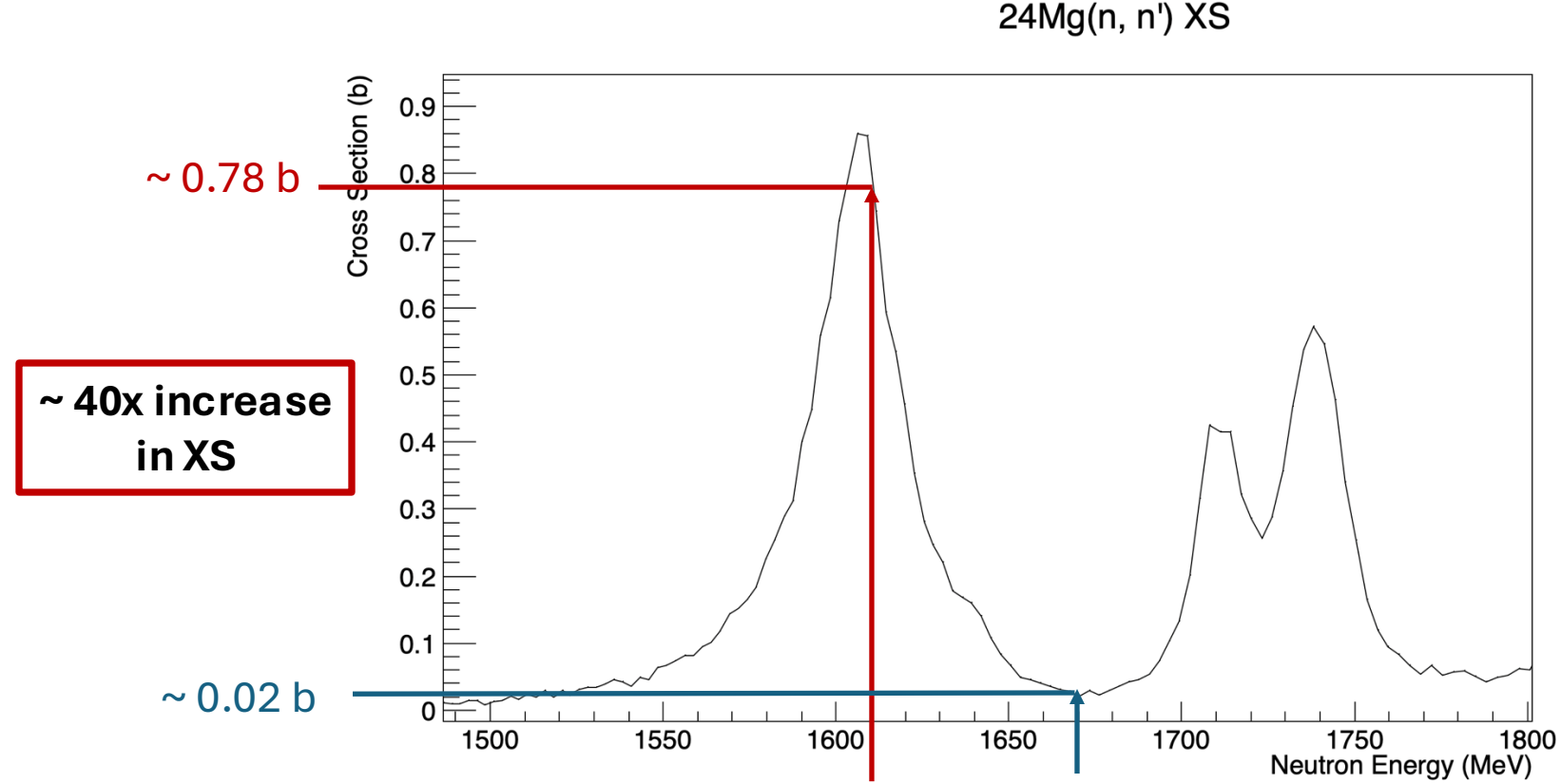
- Track gamma "limits" ($3\sigma$)
- Calculate Background



# Analysis - MS

**Inelastic Scatter NOT primary reaction**



# Analysis – MS Correction

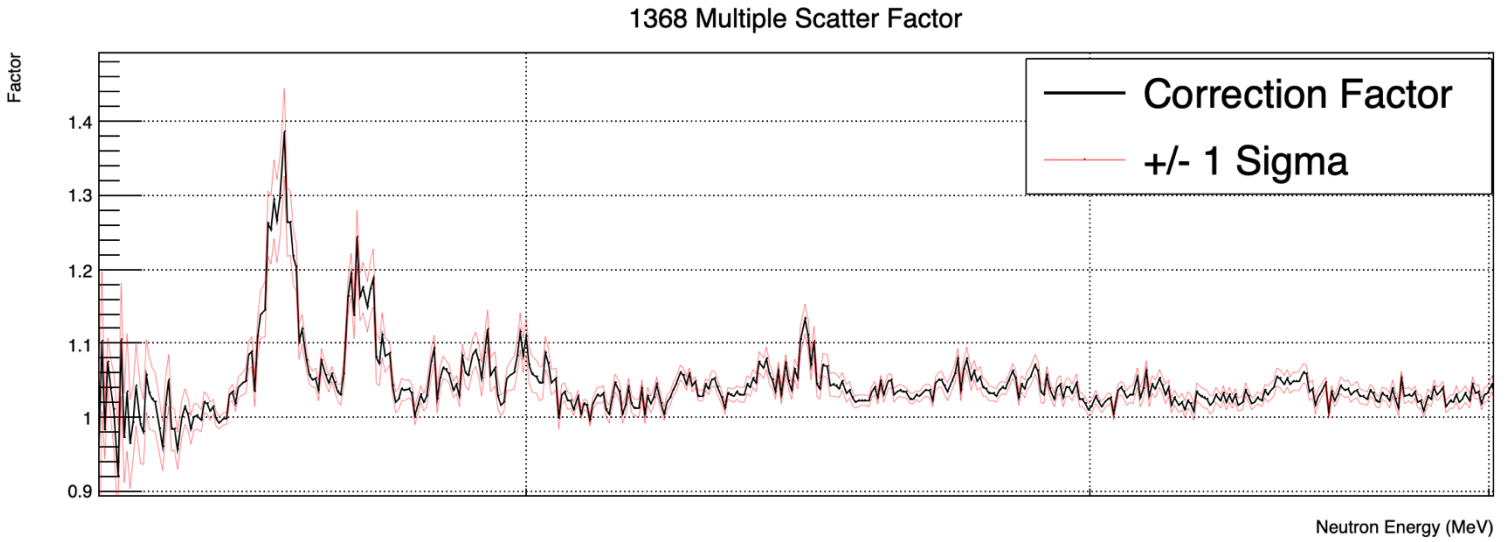
- Calculated via G4 simulations

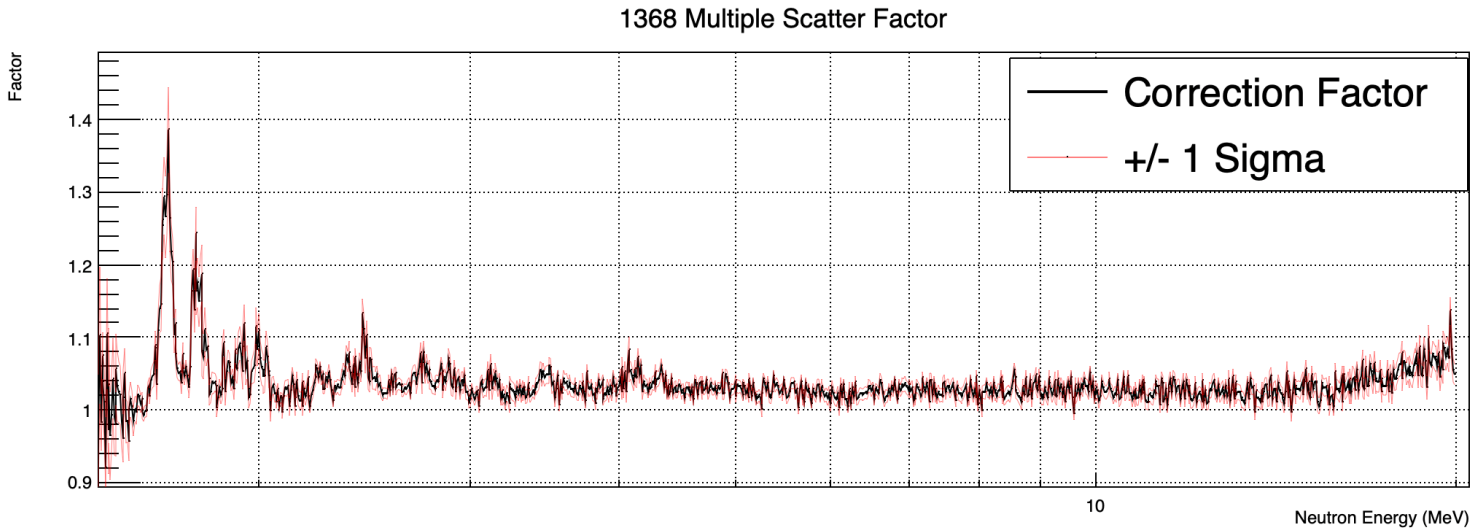
## Dependent on:

- Elastic XS ($E_n$)
- Inelastic XS ($E_n$)
- Sample Geometry

## Ratio of count rates

- Multiple Scatter allowed
- No Multiple scatter allowed



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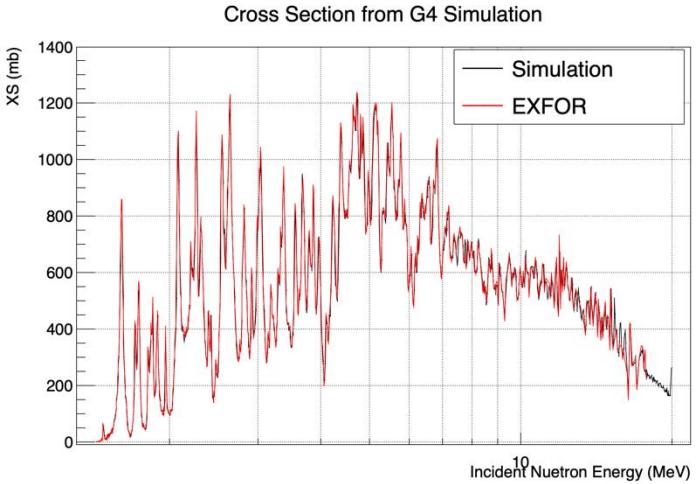


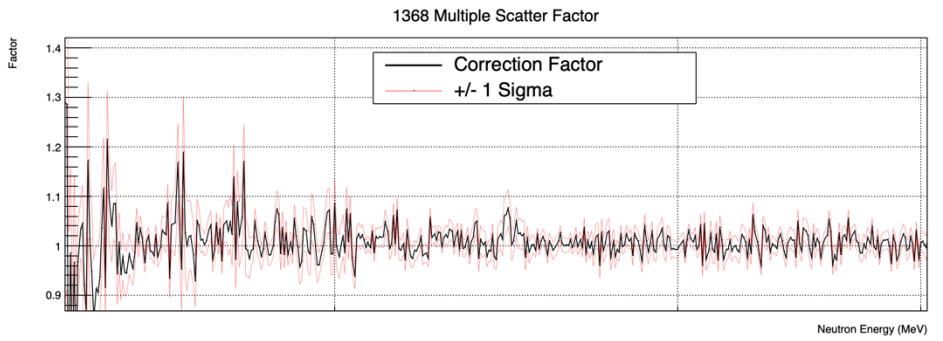


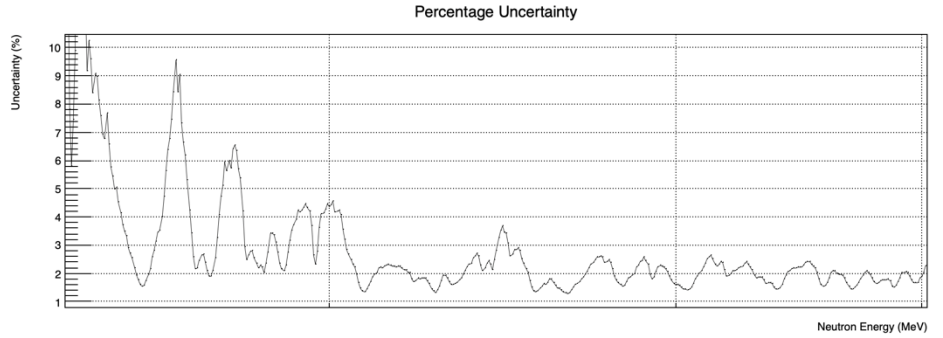


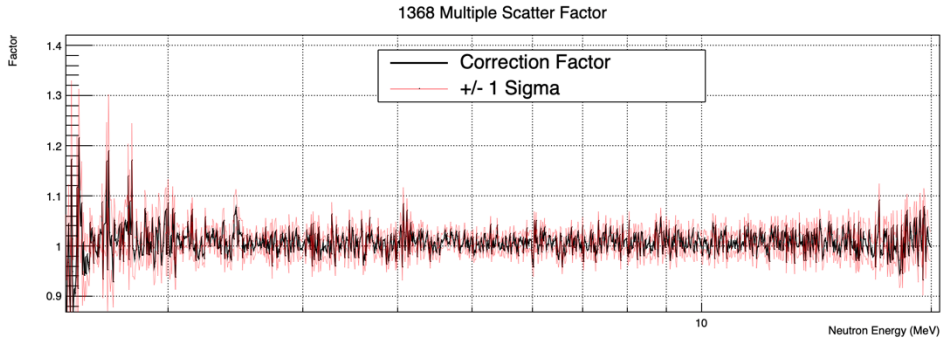


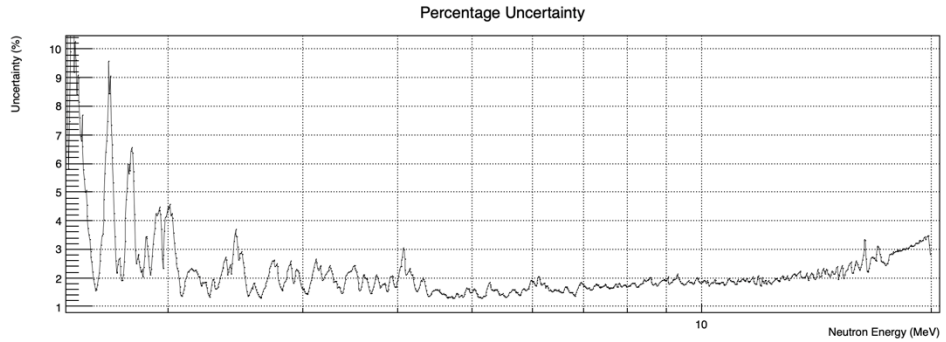

# Cross Section Calculation

$$\sigma = \frac{R}{\phi n}$$

$R$ - Reaction rate
$\phi$ - Incoming neutron flux
$n$ - Areal density

$R$ from measurement

$\phi$ from evaluated n_TOF flux

$n$ sample specific – easy to calculate

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