$p + d \rightarrow {}^3He + \eta$ cross sections

at 49 and 60 MeV excess energy at WASA-at-COSY

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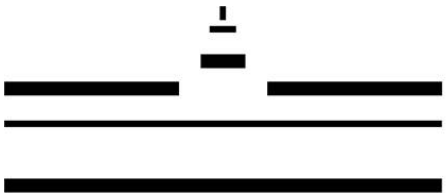
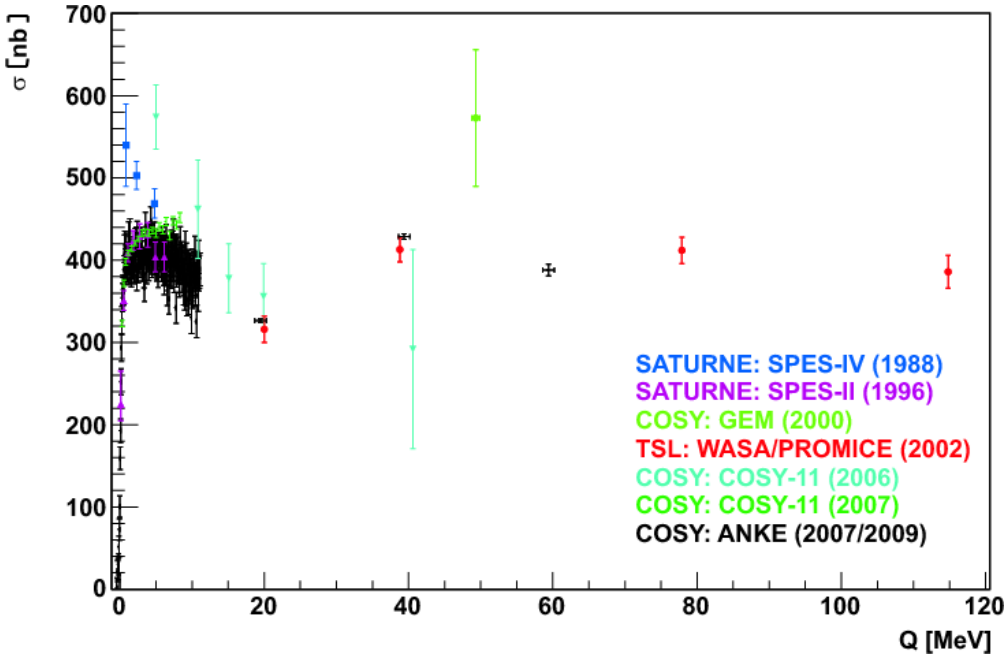


Motivation

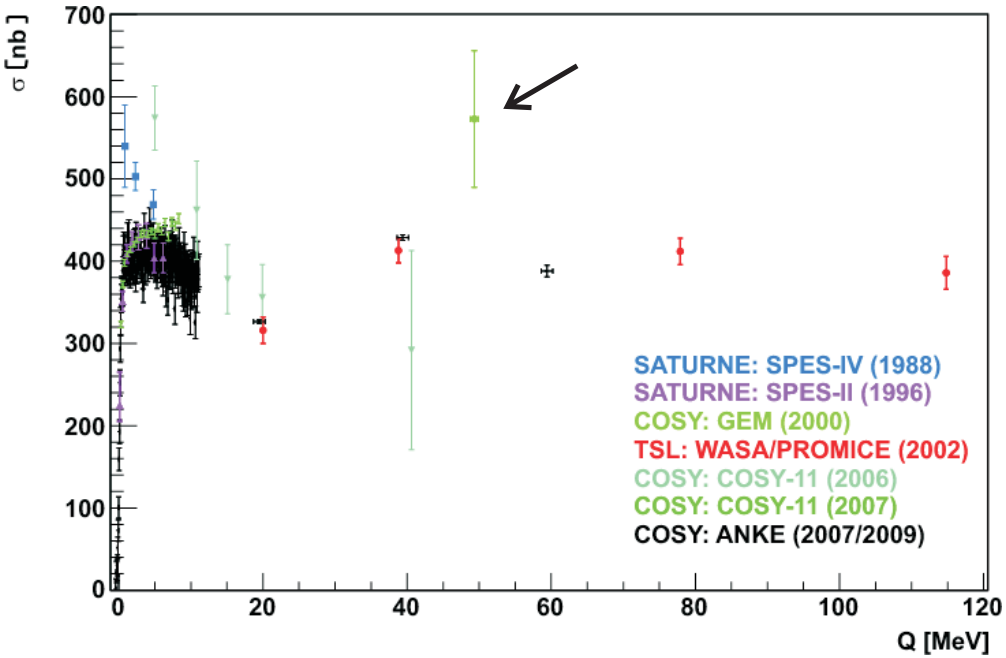
Total $p + d \rightarrow {}^3He + \eta$ cross sections (only statistical errors):

- Strong energy dependence within the first MeV excess energy caused by a strong final state interaction
- Strong evidence for an $\eta{}^3He$ bound state
- Excitation function is well known near the production threshold



Motivation

- Larger uncertainties at higher excess energies
- Data from WASA/PROMICE and ANKE show a cross section plateau between 40 and 120 MeV
- 49 MeV GEM data point might indicate a cross section increase above this plateau
- A peak-like structure would be of high interest for studies of the reaction and the final state interaction
- Enhancement can also be an artifact of different normalizations ($\approx$15 %)



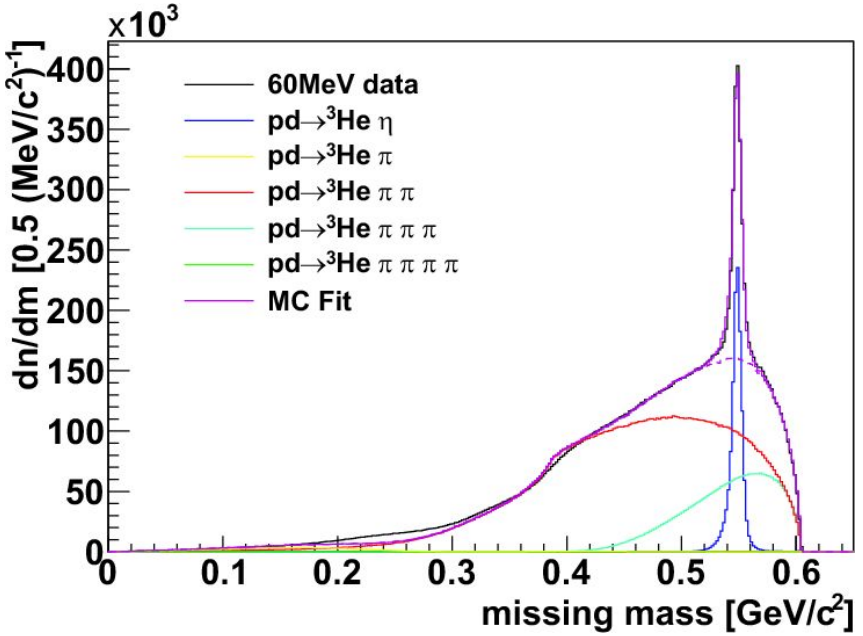
Database

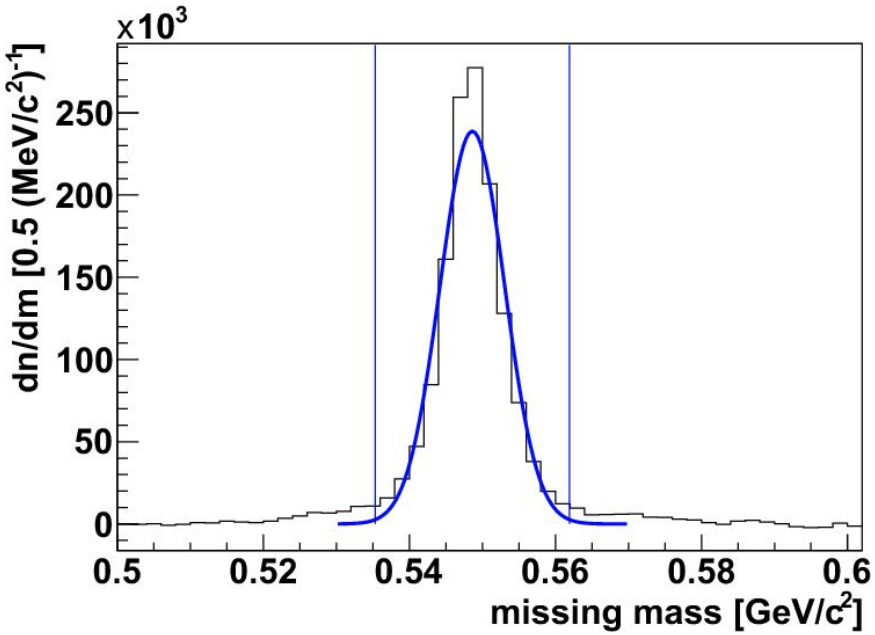
$\Rightarrow$ A new measurement at 49 MeV is of high interest to clarify the situation

- Data for the reaction $p + d \rightarrow {}^3He + \eta$ at 60 MeV excess energy were taken with the WASA-at-COSY setup (decay studies)
- To verify the GEM data point additional data were taken at 49 MeV
- Relative normalization of both data sets possible
- Data taken at same run period August/September 2009 to minimize systematic uncertainties
- Preselected data are used for the analysis (preselected on the ${}^3He$ nucleus in the Forward Detector)
- For the determination of the differential cross sections the number of η events are extracted from the missing mass spectra of different angular ranges

Number of η events

- The background for each $\cos(\vartheta_{\mathrm{CMS}})$ bin is fitted with MC simulations and subtracted
- The peak is fitted with a Gaussian distribution to determine the 3σ area
- The events are counted in this area and are corrected to 100 %
- The extracted η numbers are corrected to the detector acceptance





Normalization

- With known luminosity L and number of η events N_η the differential cross section for the i-th $\cos(\vartheta_{\mathrm{CMS}})$ bin can be determined via:

$$\left(\frac{d\sigma}{d\Omega}\right)_i = \frac{1}{4\pi}\frac{N_{\eta,i}}{L}$$

- The total cross section can be calculated by:

$$\sigma_{\mathrm{total}} = \sum_i 2\pi \cdot \Delta\cos(\vartheta_{\mathrm{CMS}}) \left(\frac{d\sigma}{d\Omega}\right)_i$$

- Aim: determination of the ratio $\frac{\sigma(49\,\mathrm{MeV})}{\sigma(60\,\mathrm{MeV})}$

Normalization

- Relative normalization is done via the single pion production
  $p + d \rightarrow {}^3He + \pi^0$
- The excess energies for the single pion production are $Q = 462\,\text{MeV}$ and $Q = 473\,\text{MeV}$ respectively for the two data samples
- The phase space volume changes by approximately 1 % only:

$$\sqrt{\frac{Q = 473\,\text{MeV}}{Q = 462\,\text{MeV}}} \approx 1{,}01$$

$\Rightarrow$ The π^0 ratio corresponds to the ratio of the integrated luminosities and is used as normalization factor

$\Rightarrow$ Absolute normalization to the 60 MeV ANKE cross section

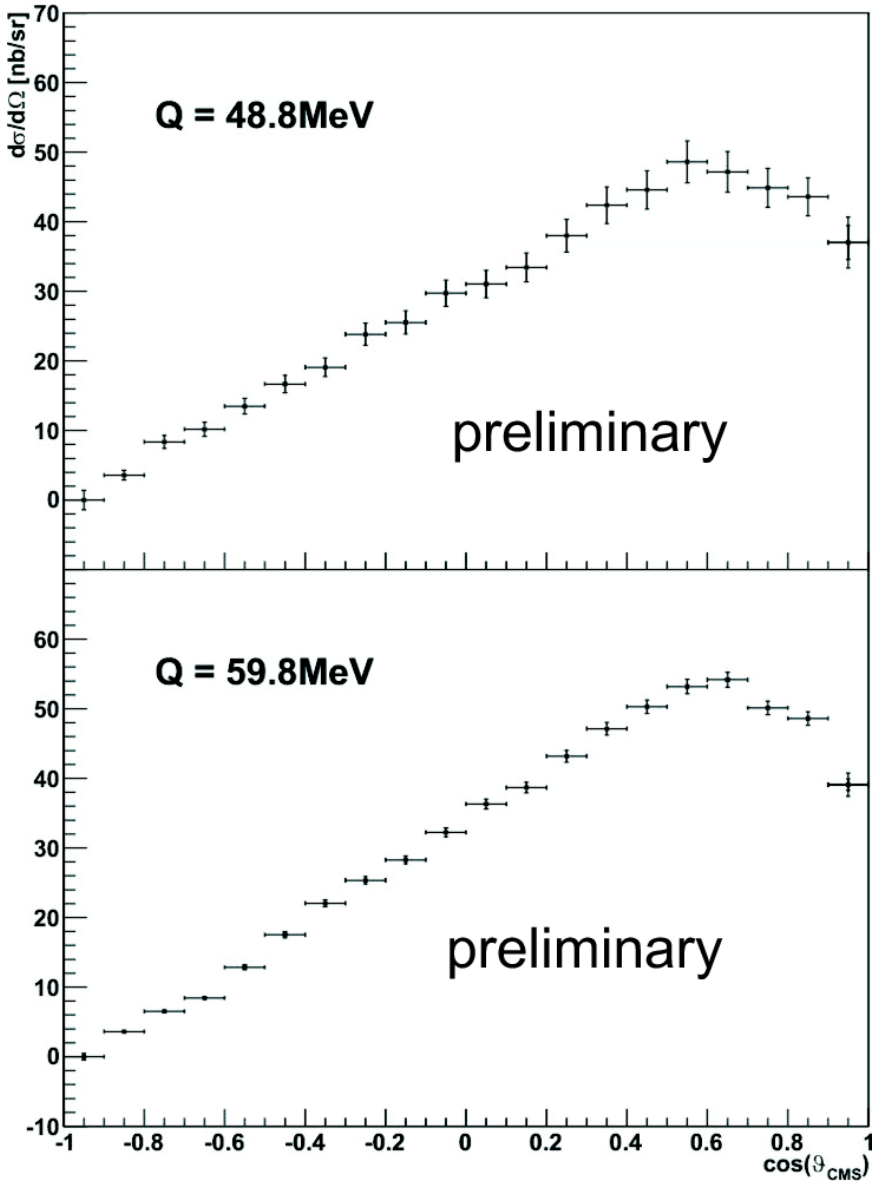
Normalization

- Preliminary result:

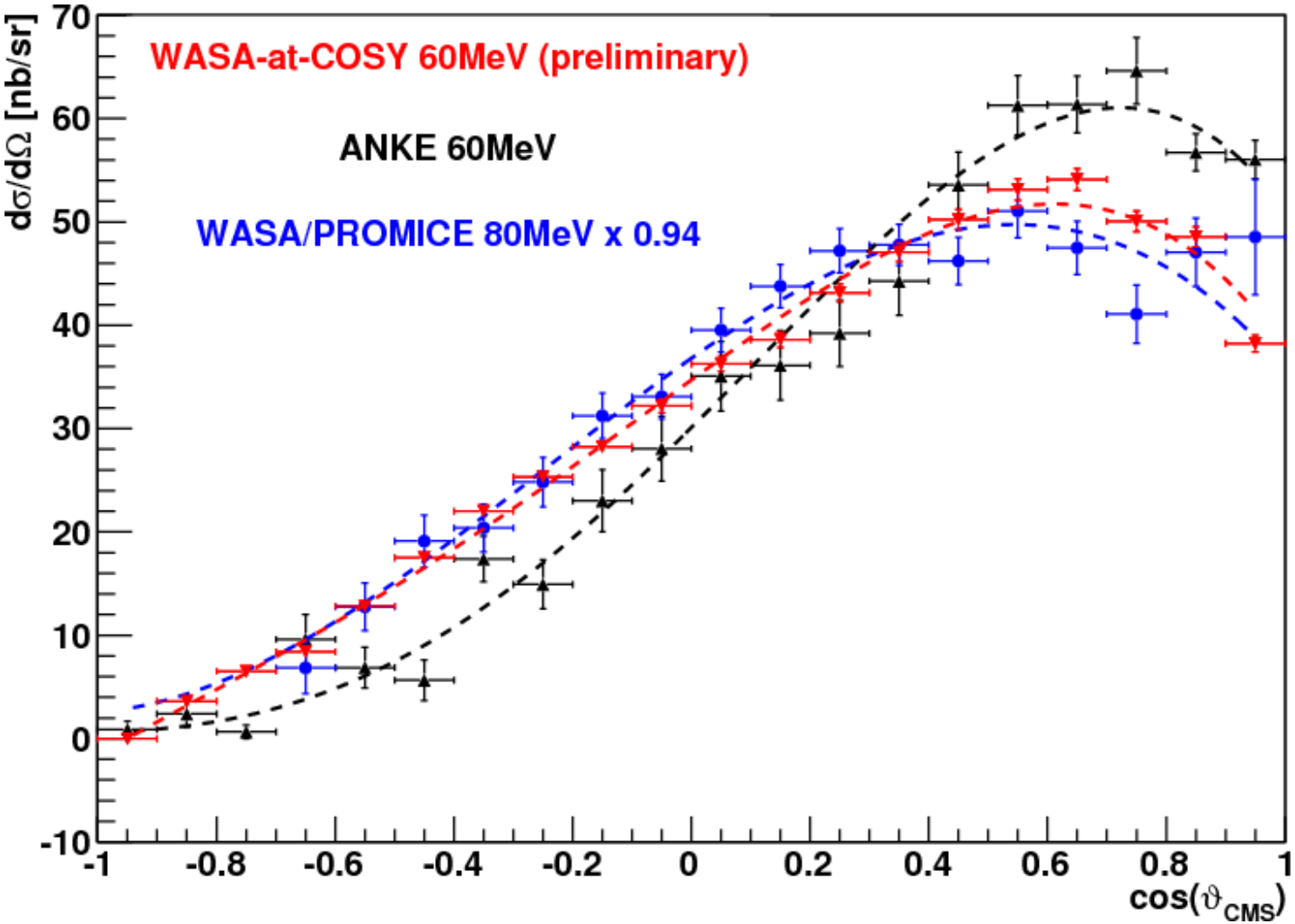
$$\frac{\sigma(49\,\mathrm{MeV})}{\sigma(60\,\mathrm{MeV})} = 0.98 \pm 0.06$$

  $\Rightarrow$ No peak-like structure at 49 MeV

- $\sigma_{\mathrm{ANKE}}(60\,\mathrm{MeV}) = (388.1 \pm 7.1)\,\mathrm{nb}$
- The normalization to the 60 MeV ANKE data leads to a preliminary cross section at 49 MeV of $\boldsymbol{\sigma(49\,\mathrm{MeV}) = (379.3 \pm 22.8)\,\mathrm{nb}}$
- Additional normalization error of 15 %
- The measured data point agrees well with the described plateau

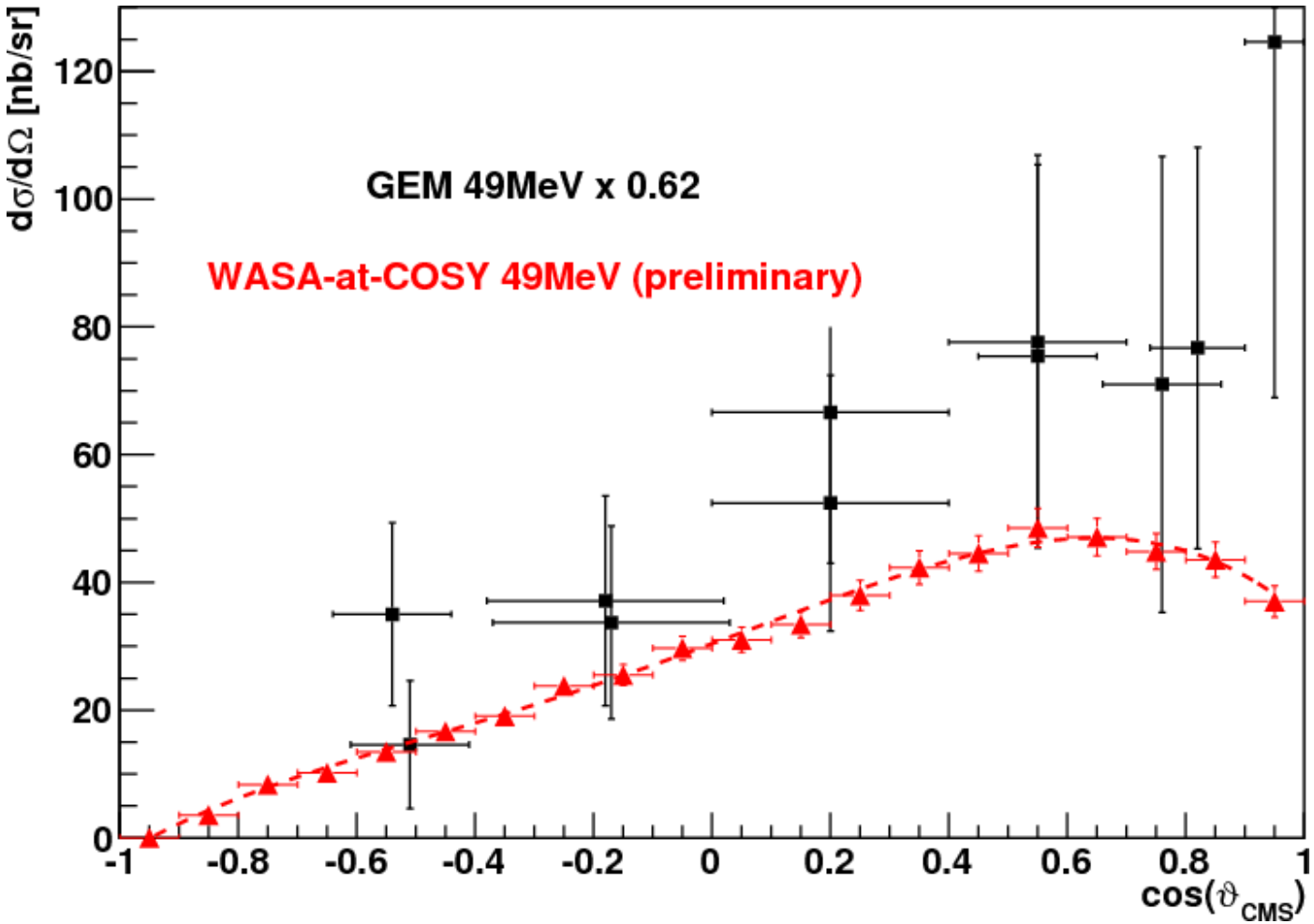


Differential cross sections



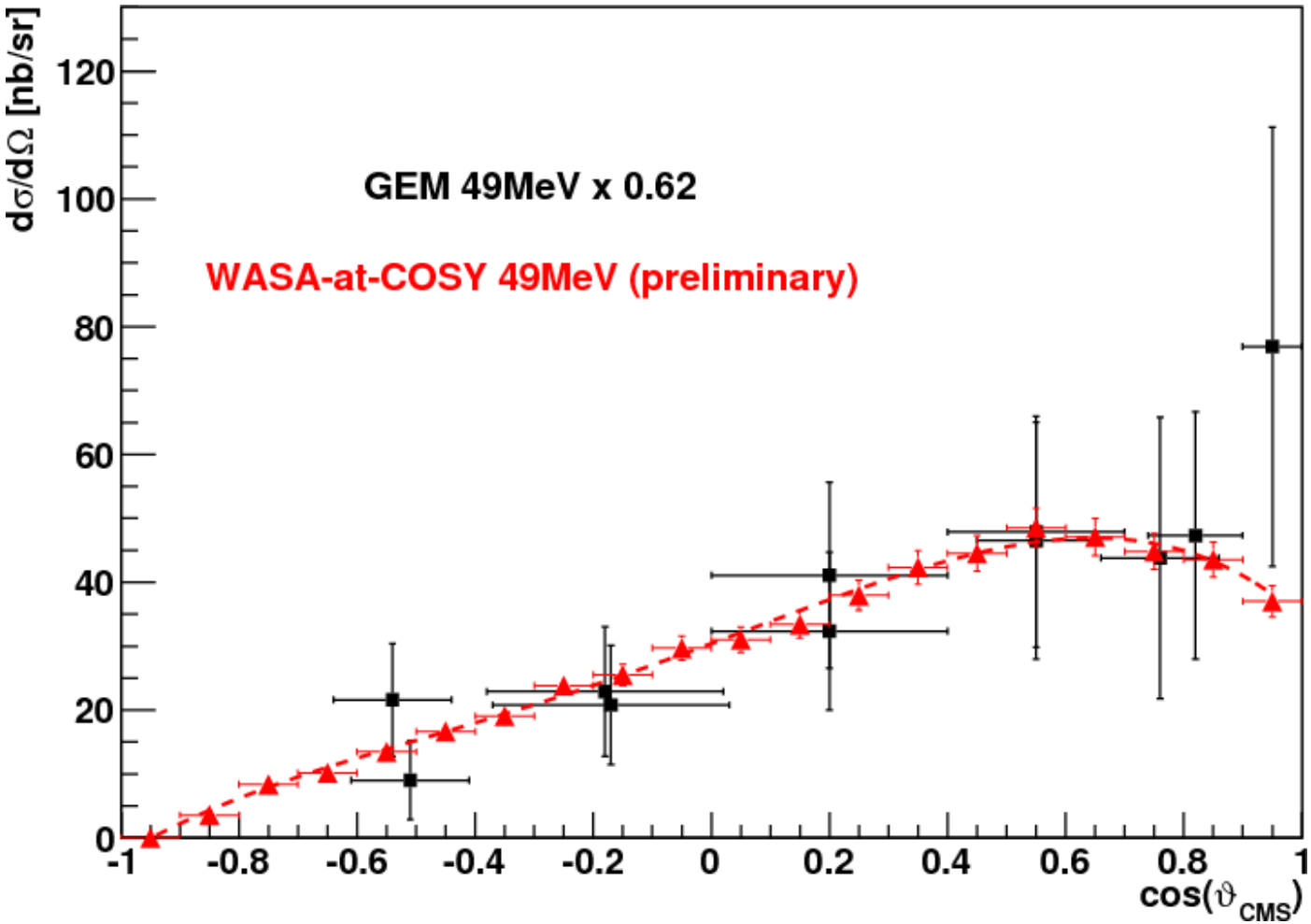
- Comparison of the differential cross sections at $Q = 60\,\mathrm{MeV}$

Differential cross sections



- Comparison of the differential cross sections at $Q = 40\,\mathrm{MeV}$ and $Q = 49\,\mathrm{MeV}$

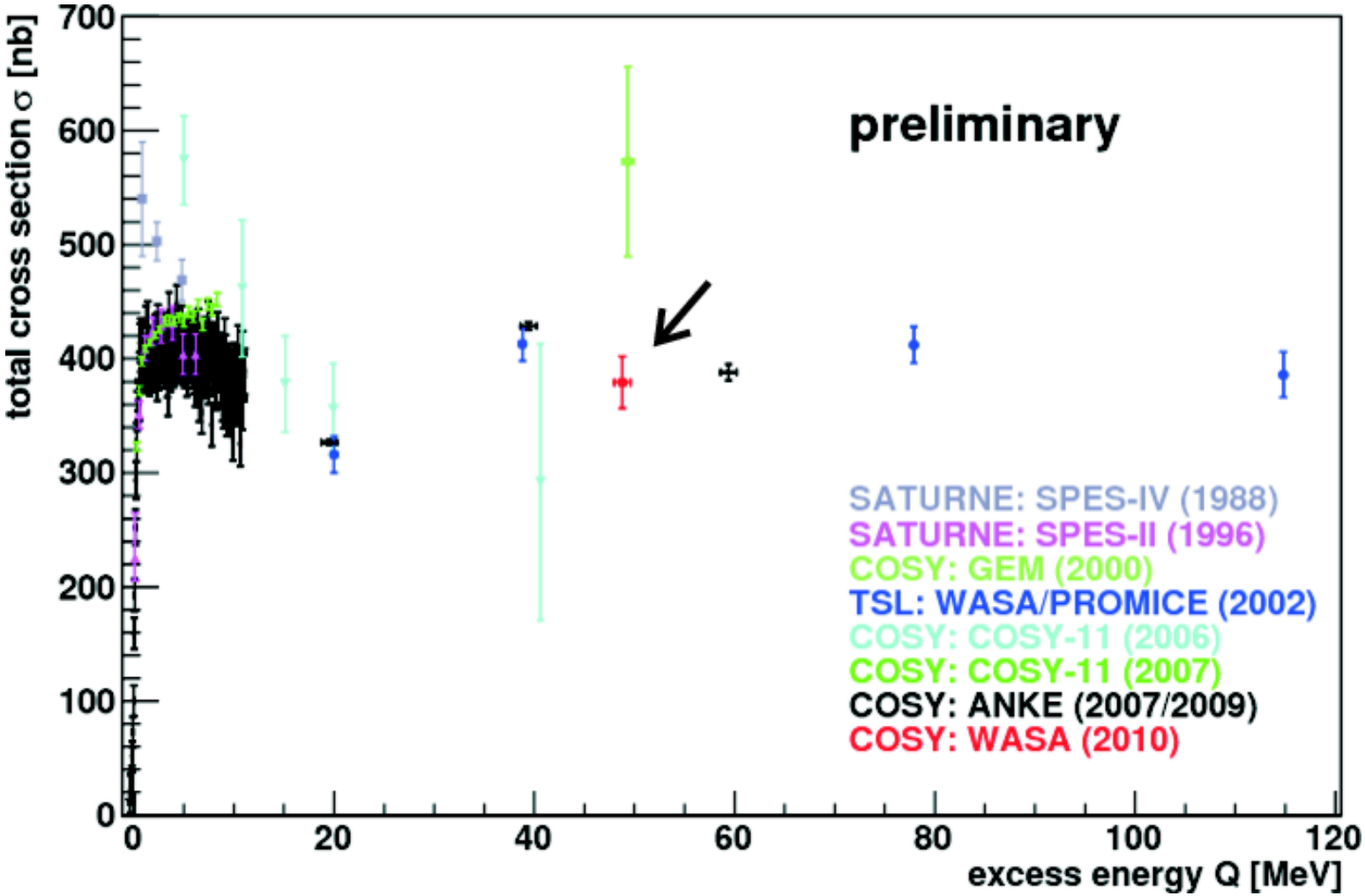
Differential cross sections



- Comparison of the differential 49 MeV WASA-at-COSY cross sections to the scaled GEM data

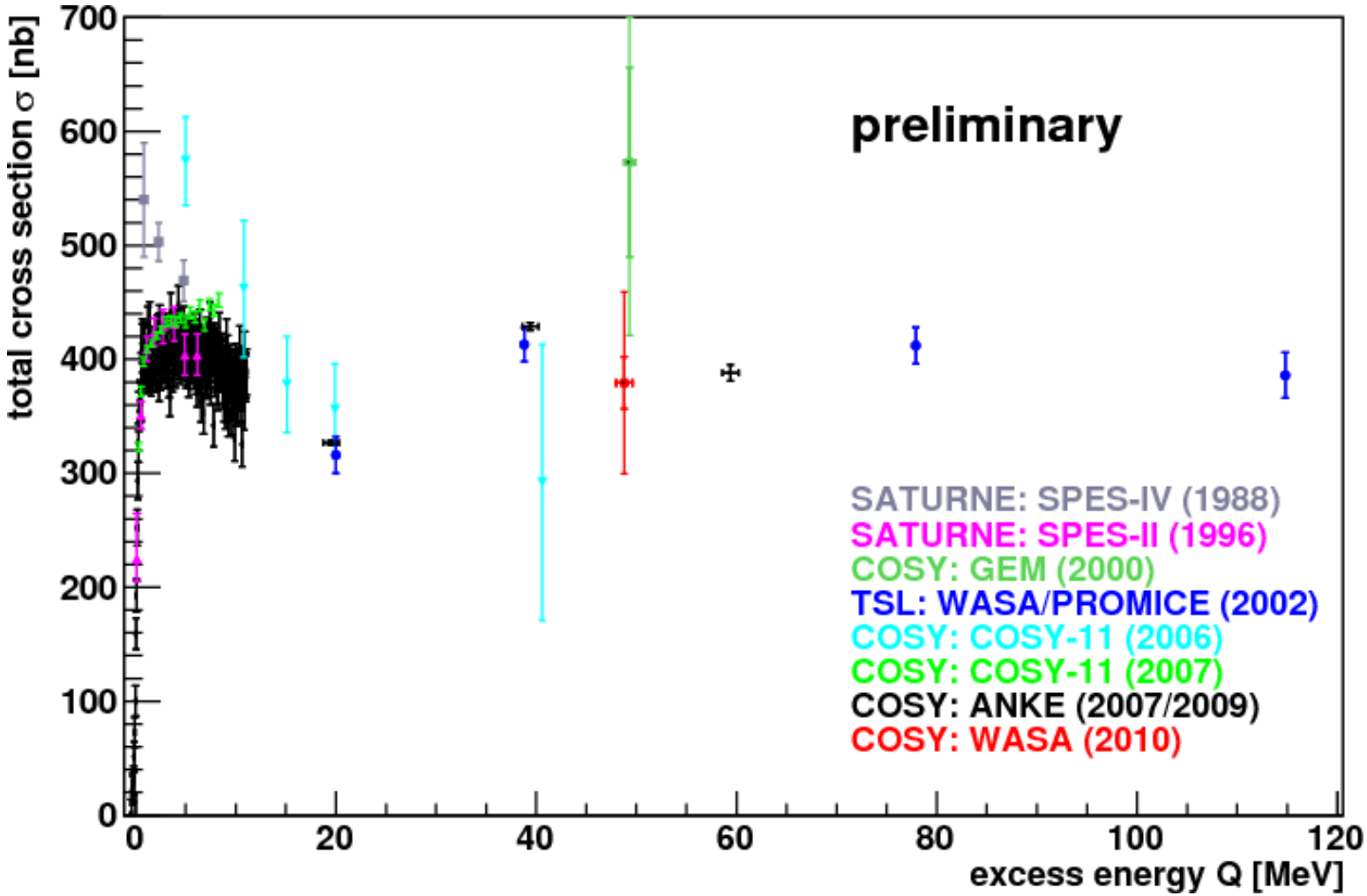
Total cross sections

- Total cross sections with statistical uncertainties, but without normalization errors



Total cross sections

- Total cross sections with statistical uncertainties and with normalization errors for the 49 MeV data



Conclusion

- Angular distributions of the $p + d \rightarrow {}^3He + \eta$ reaction at 49 and 60 MeV excess energy were extracted
- With the normalization to the 60 MeV ANKE data and via the single pion production differential and total cross sections were determined
- There is no peak-like structure in the excitation function at 49 MeV
- Concerning statistical and systematical uncertainties the new 49 MeV WASA-at-COSY data are not in disagreement with the 49 MeV GEM data:
  $\sigma^{\text{prel.}}_{\text{WASA}}(49\,\text{MeV}) = (379 \pm 23)\,\text{nb} + 57\,\text{nb}$ normalizatien error
  $\sigma_{\text{GEM}}(49\,\text{MeV}) = (573 \pm 83)\,\text{nb} + 69\,\text{nb}$ normalization error
- The deviation is due to different normalizations, but the angular distributions are in agreement

The End!

Thank you for your attention!