Spectrum Related SACS Uncertainties

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Background

- **Neutron Dosimetry Library IRDFF-II**
  - Evaluated SACS and their uncertainties for many reactions and neutron spectra that are important for reactor neutron dosimetry are provided in this library.
  - Most of the reactions associated with the Neutron Standards are also included there.
  - Documentation:
    - A. Trkov et al., IRDFF-II: A New Neutron Metrology Library, *Nuclear Data Sheets* **163** (2020) 1-108. It is also available as arXiv 1909.03336 (2019).
    - International Reactor Dosimetry and Fusion File, IRDFF-II, Nuclear Data Services, International Atomic Energy Agency, Vienna. Website: https://www-nds.iaea.org/. (January 2020).

- **Tabulated SACS Evaluated Uncertainty Data from IRDFF-II**
  - See Table 18 located in the *Nuclear Data Sheets* paper (p. 72).
  - A printout of relevant numerical uncertainty values, generated by Andrej Trkov employing code RR_UNC and the IRDFF-II Library, was made available for use in the present investigation via a private communication from Roberto Capote.

Computational Formalism

SACS Definition

$$SACS = \langle\sigma\rangle = \int \sigma(E)\,\phi(E)\,dE \qquad (\phi \text{ normalized})$$

SACS Group Representation

$$\langle\sigma\rangle \approx \sum_i \sigma_i\,\phi_i$$

SACS Uncertainty (Variance)

$$Var(SACS)_{tot} = Var(SACS)_{\phi} + Var(SACS)_{\sigma} \approx \boldsymbol{\sigma}\,\mathbf{V}_{\phi}\,\boldsymbol{\sigma}^{T} + \boldsymbol{\phi}\,\mathbf{V}_{\sigma}\,\boldsymbol{\phi}^{T}$$

Scope of the Present Investigation

- Useful parameters for investigating SACS data are $E_{50\%}$, Emedian, and Emean, as defined by:

$$\int\{0,E_{50\%}\}\ \sigma(E)\ \phi(E)\ dE = \int\{E_{50\%},\infty\}\ \sigma(E)\ \phi(E)\ dE \quad ||||| \quad \int\{0,\infty\}\ \phi(E)\ dE = 1 \quad (\phi \text{ normalized})$$

$$\int\{0,\text{Emedian}\}\ \phi(E)\ dE = 0.5 \quad ||||| \quad \text{Emean} = \int\{0,\infty\}\ E\ \phi(E)\ dE$$

- The present investigation is confined to considering only the SACS uncertainties from IRDFF-II dosimetry reaction data set and the Cf-252(s.f.) neutron spectrum, as reported by Andrej Trkov.

- Tabulated SACS Cf-spectrum-related uncertainty values "Unc. Sp." = SQRT[Var(SACS)ϕ] were extracted from the abovementioned sources, categorized by reaction type, organized according to their associated $E_{50\%}$ values and subsequently plotted vs. $E_{50\%}$ along with polynomial fits.

- Trends in these plotted "Unc. Sp." values vs. $E_{50\%}$ are noted and conclusions are offered.

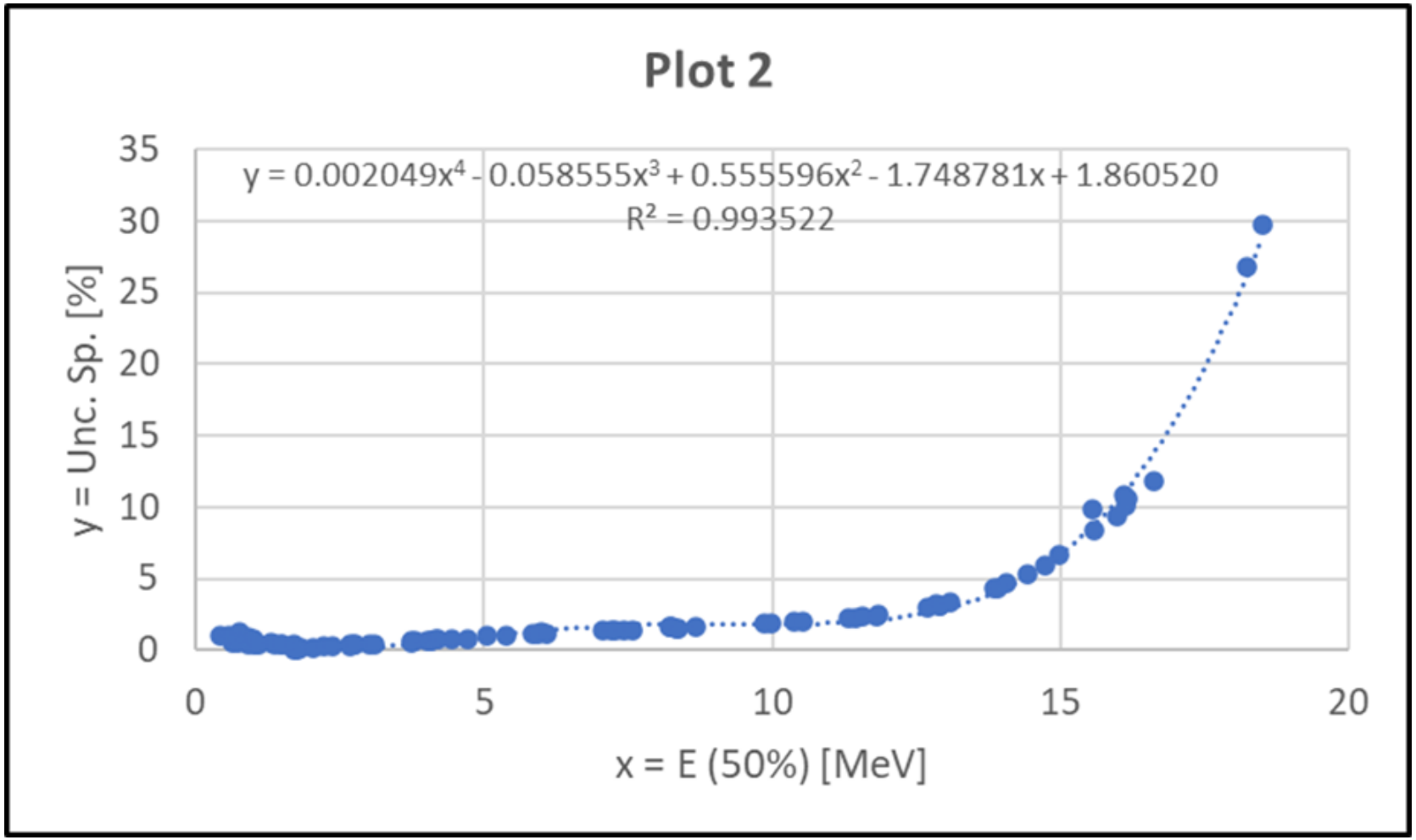
Results from this Investigation

- Uncertainty information relevant to the following reactions associated with the Neutron Standards can be found in the IRDFF-II Library: 6Li(n,t), 10B(n,α), 10B(b,α$_1$γ), Au(n,γ), 235U(n,f), 238U(n,f), 238U(n,γ), and 239Pu(n,f). They are included in the present work.

- Details from this work are documented in the IAEA Nuclear Data Section Report **INDC(NDS)-0864** by D.L. Smith (November 2022).

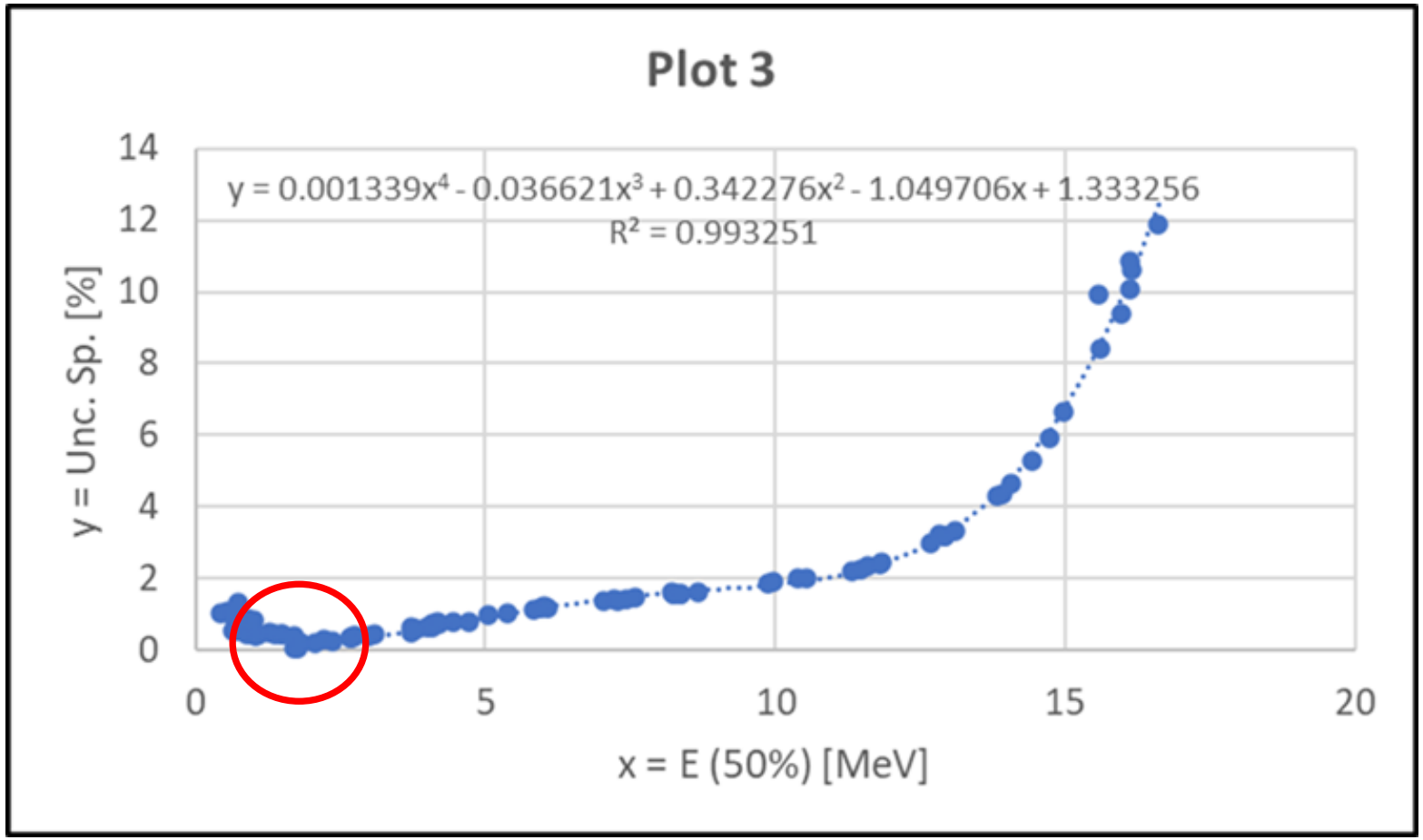
- Plots taken from this document appear in the following slides, accompanied by a few pertinent comments.
  - Note that the plot numbers ("Plot xx") appearing in the following slides correspond to the specific plots extracted from the abovementioned report.

SACS Cf-Spectrum-Related Uncertainties for All IRDFF-II Cross Sections with E(50%) < 20 MeV



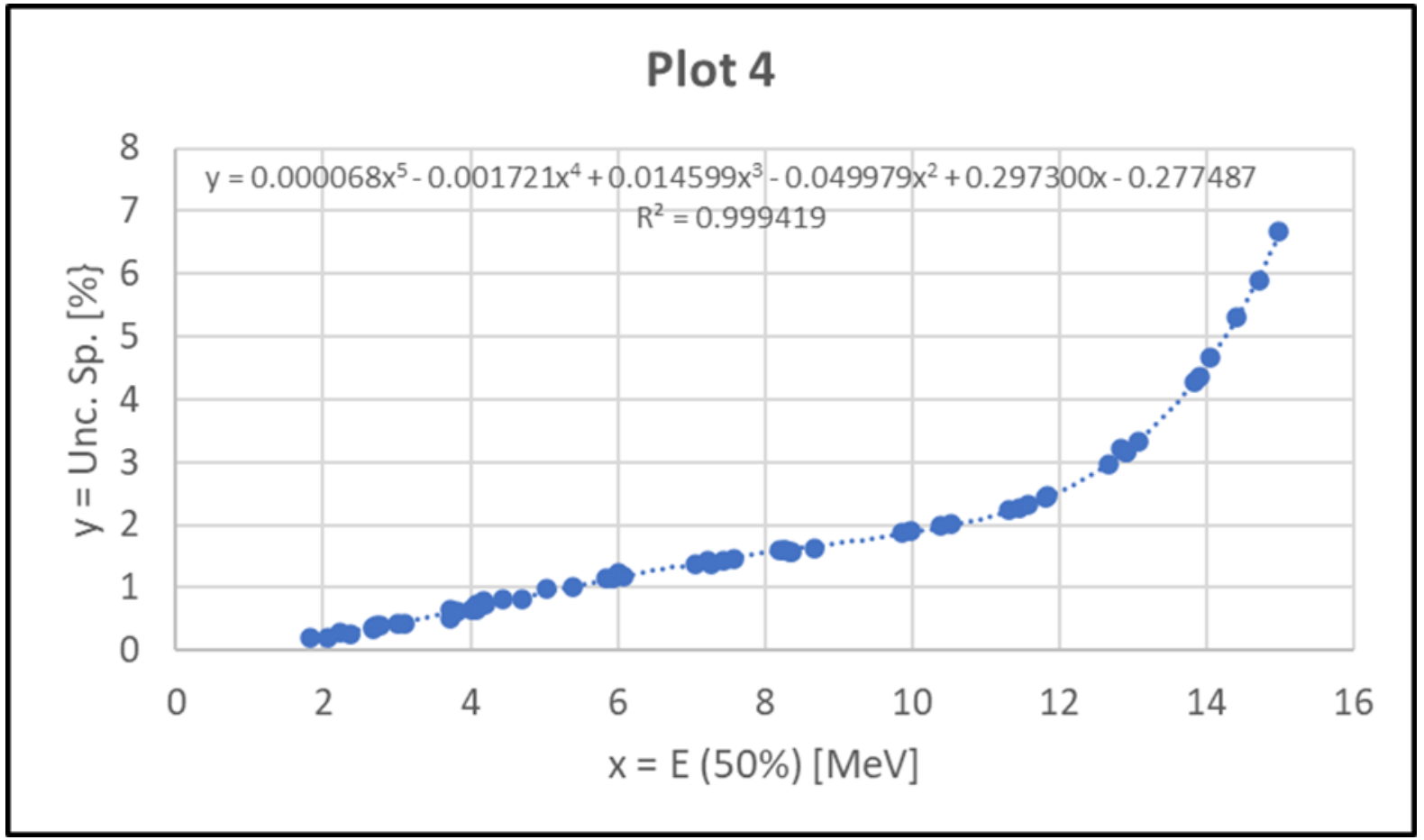
- Uncertainties increase steadily from near zero to 30% for E(50%) > 2 MeV

SACS Cf-Spectrum-Related Uncertainties for All IRDFF-II Cross Sections with E(50%) < 17 MeV



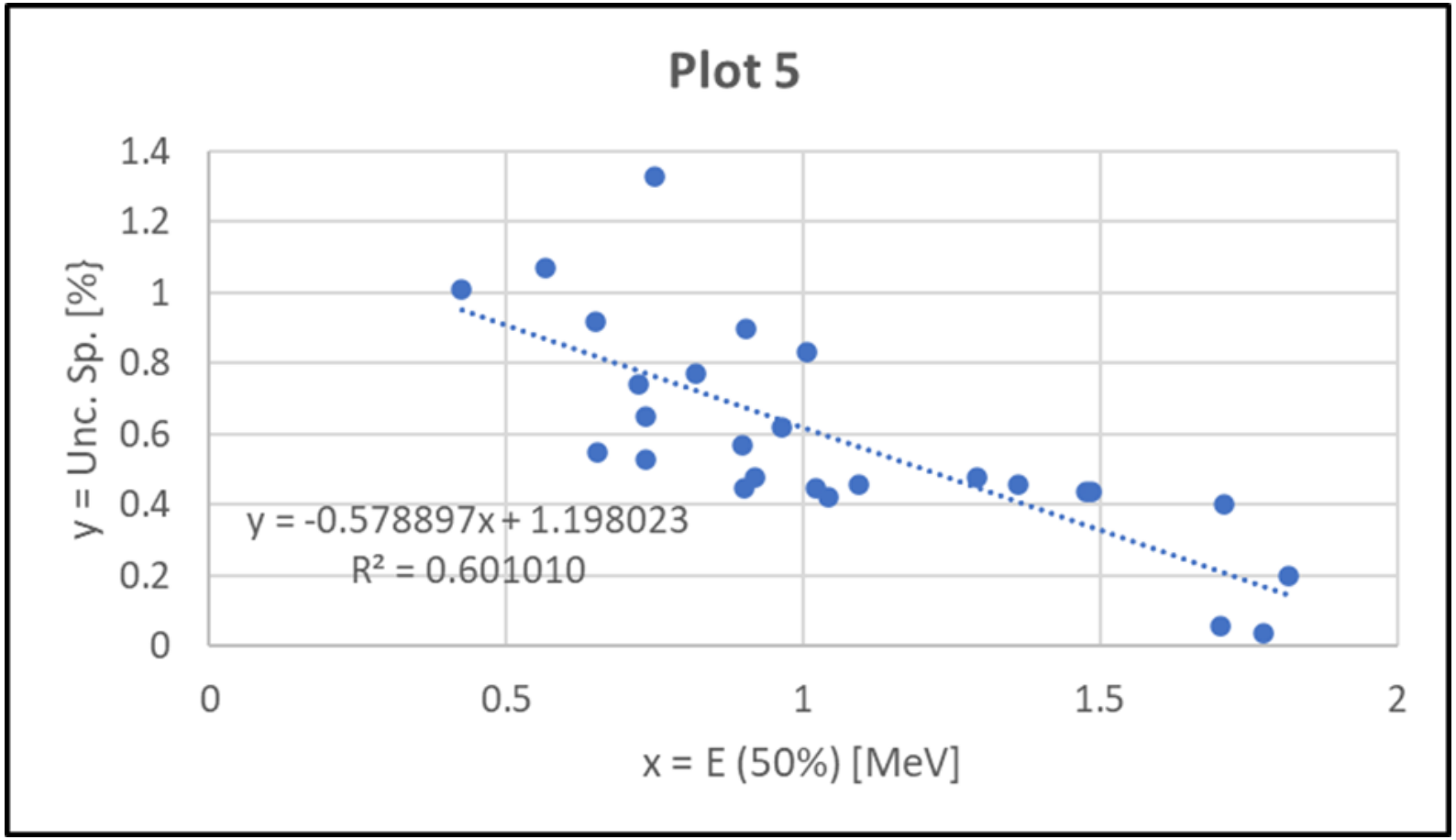
- The uncertainties are at a minimum near zero for E(50%) around 2 MeV due to low uncertainties in the spectrum values in this region as well as the balancing influence of positive and negative correlations in the normalized spectrum covariance matrix. Note that the energy mean value of the Cf spectrum is about 2.1 MeV.

SACS Cf-Spectrum-Related Uncertainties for All IRDFF-II Cross Sections with 2 MeV < E(50%) < 15 MeV



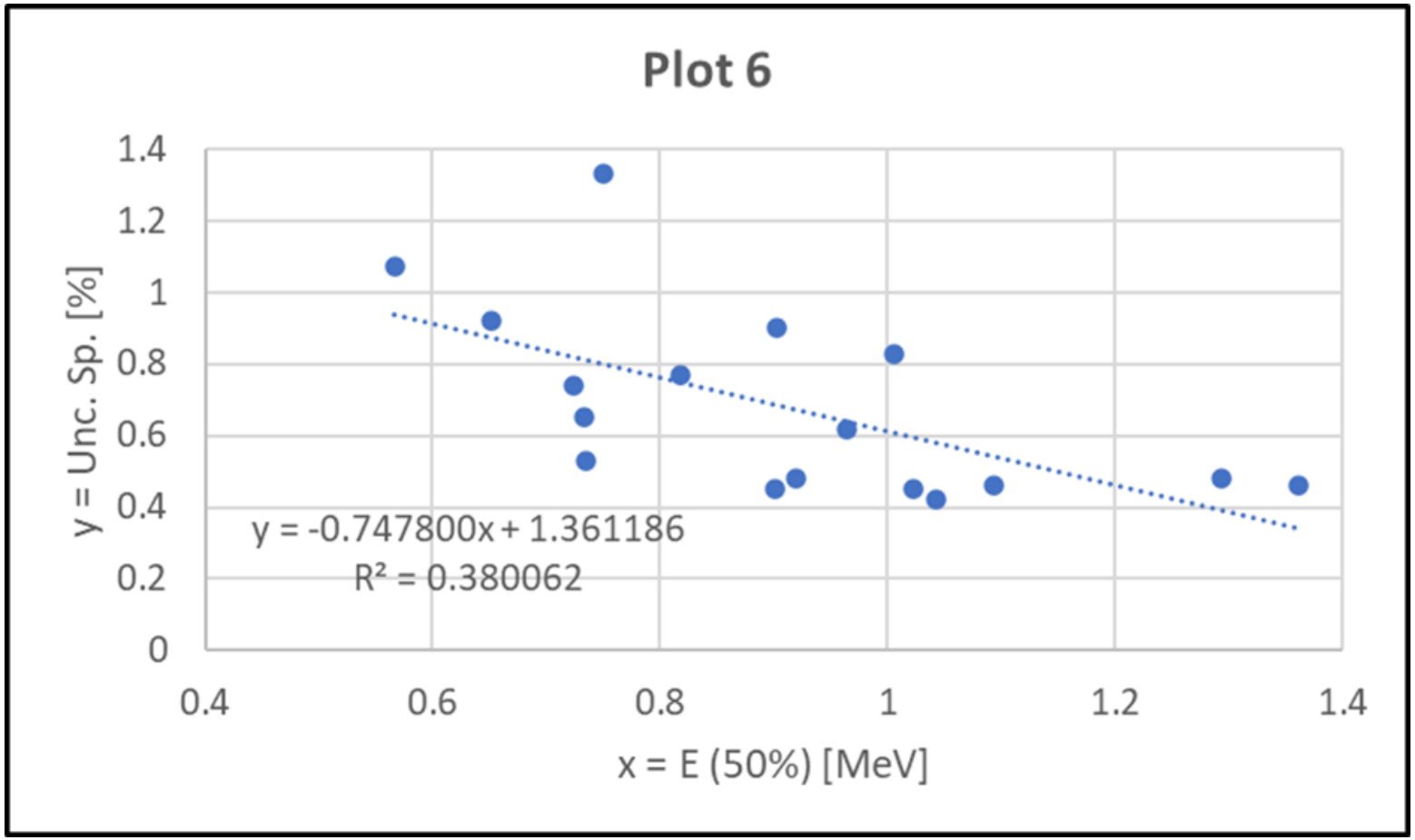
- All the data points agree very well with a smooth fitted 5th-order polynomial curve.

SACS Cf-Spectrum Related Uncertainties for All IRDFF-II Cross Sections with 2 MeV < E(50%)



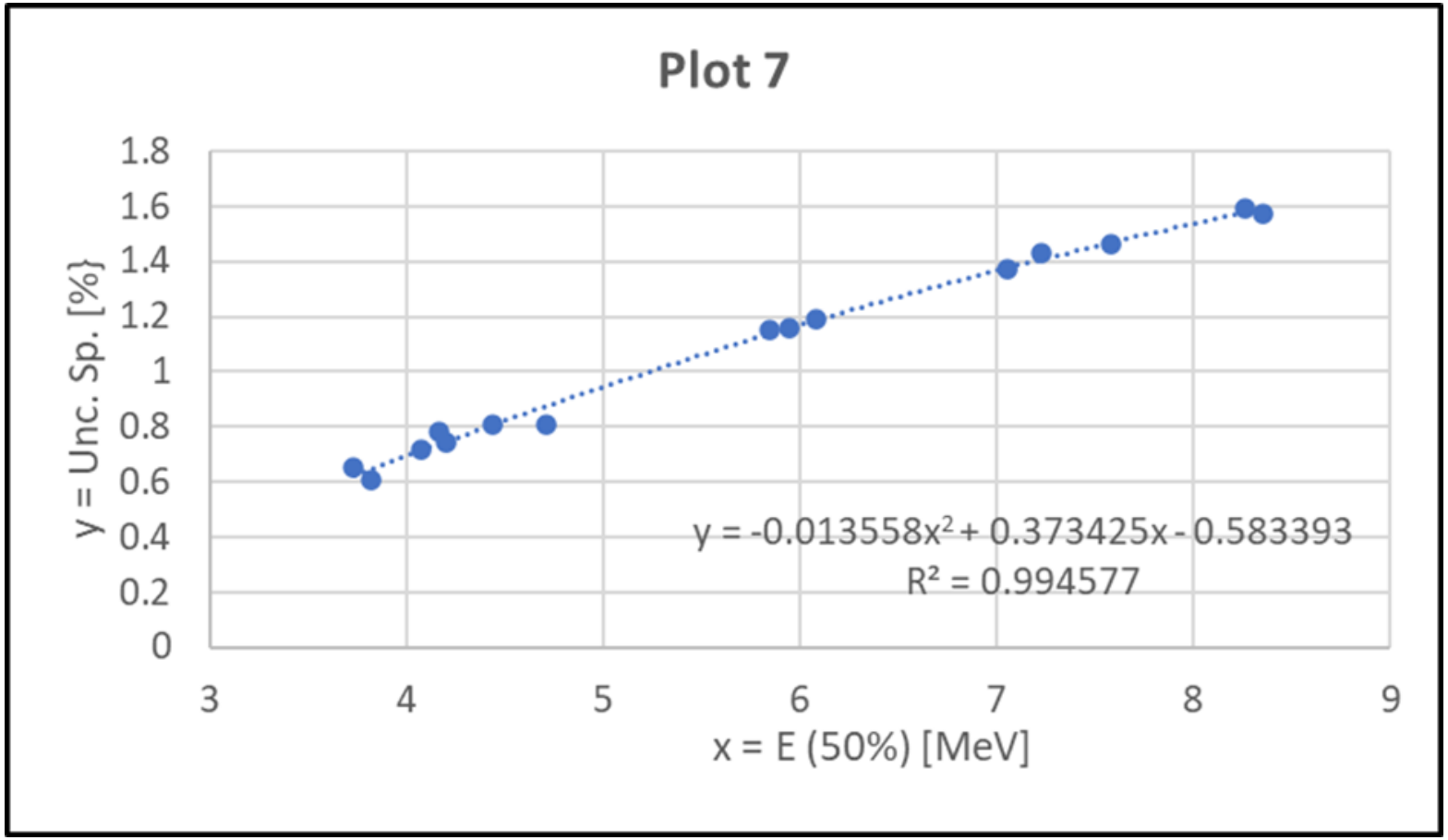
- The uncertainties are fairly small, but they do scatter considerably due to structure in many of the included cross sections.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II (n,γ) Cross Sections



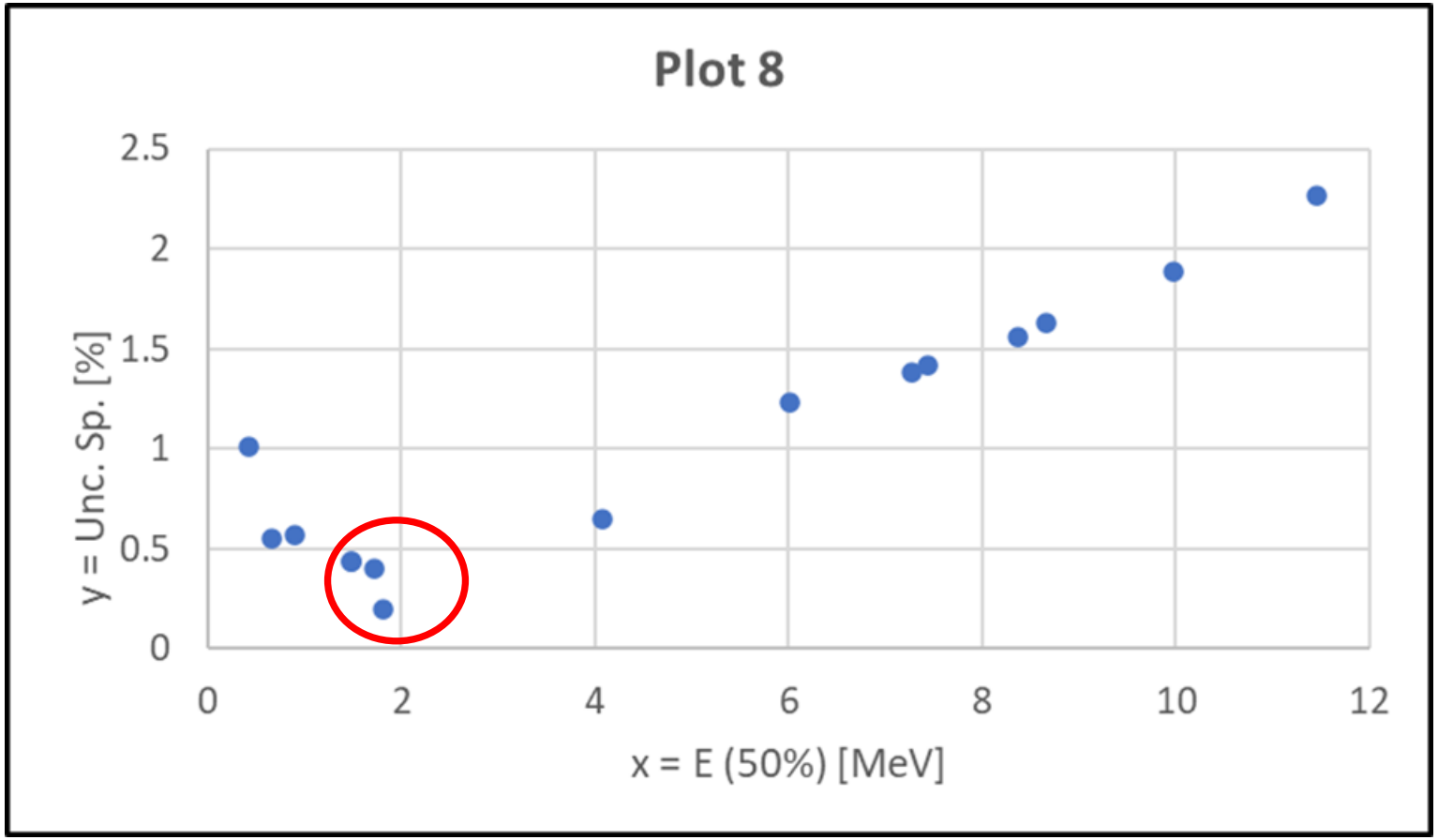
- The observed scatter in uncertainty values are likely due to the low-energy resonance structure in capture cross sections.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II (n,p) Cross Sections



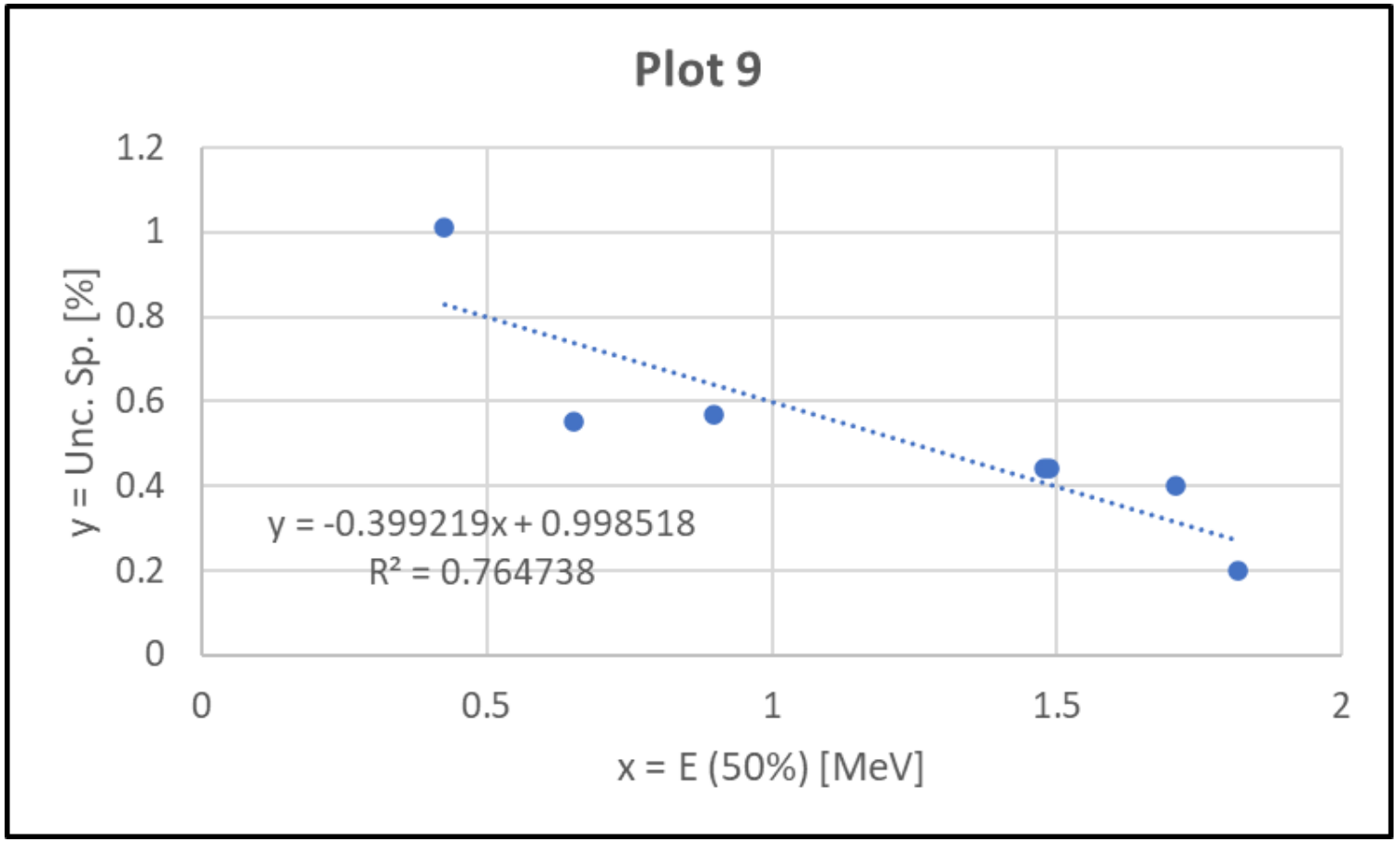
- The observed uncertainties agree fairly well with a smooth fitted quadratic polynomial curve.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II Helium Production Cross Sections



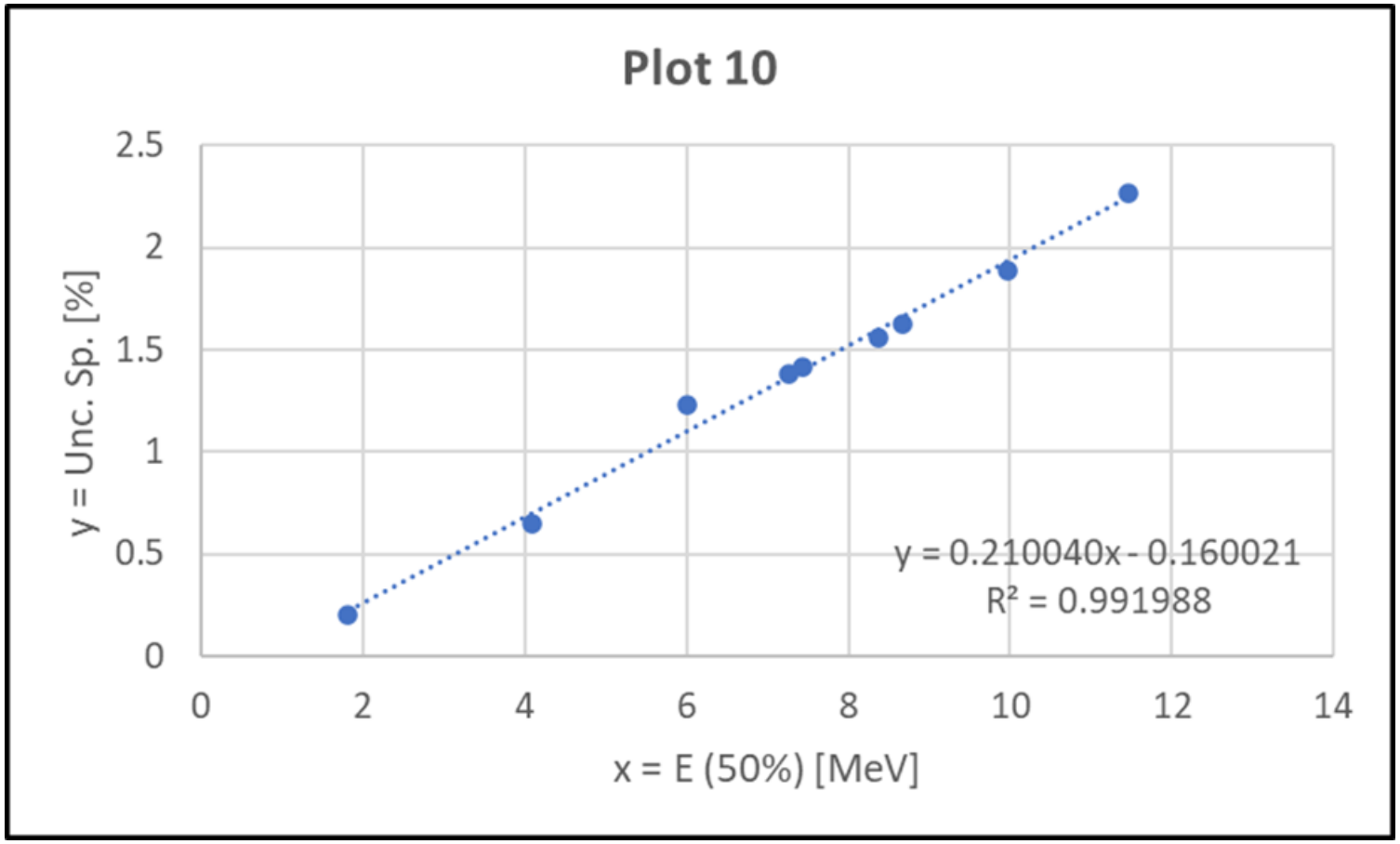
- The behavior of the uncertainties above and below the E(50%) = 2 MeV region is quite different.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II
Helium Production Cross Sections for E(50%) < 2 MeV



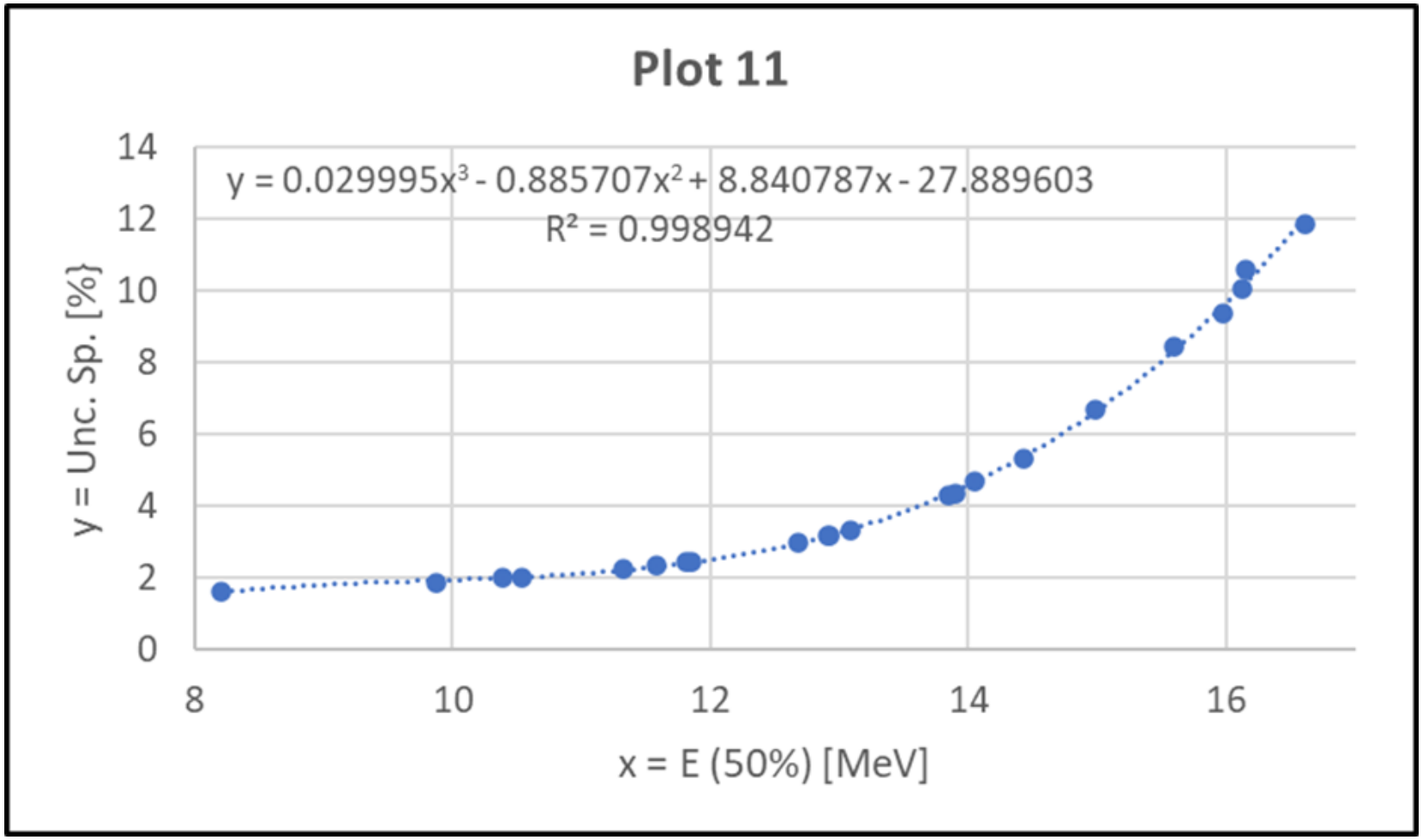
- The data points can be fitted roughly with a straight line, but the scatter about this line is considerable. The uncertainties are small (< 1%). These are all light-nuclei reactions.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II
Helium Production Cross Sections for E(50%) > 2 MeV



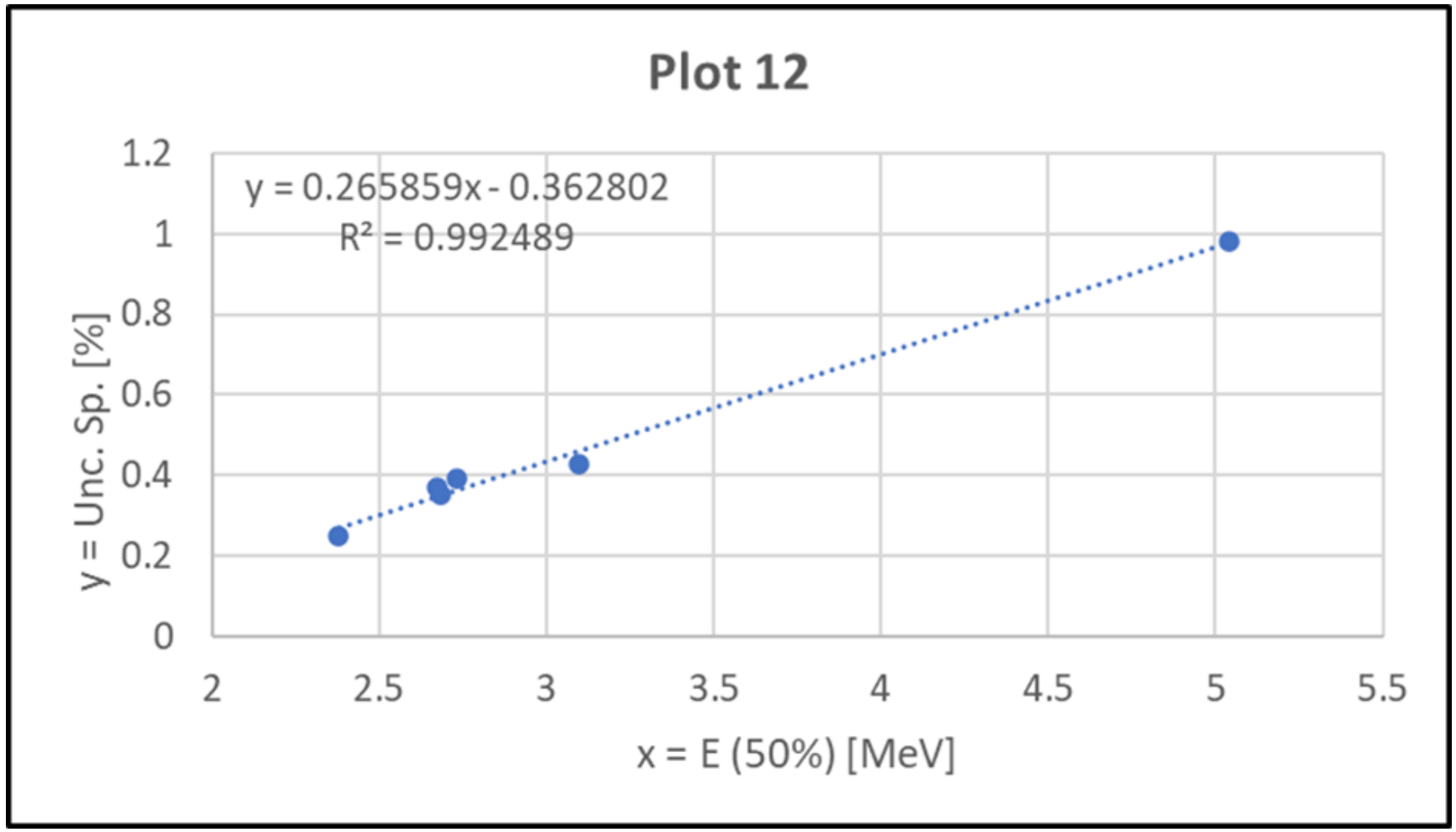
- With the exception of a single data point at E(50%) = 6 MeV (corresponding to the 7Li(n,t)He-4 reaction) these data agree well with a fitted straight line.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II (n,2n) Cross Sections



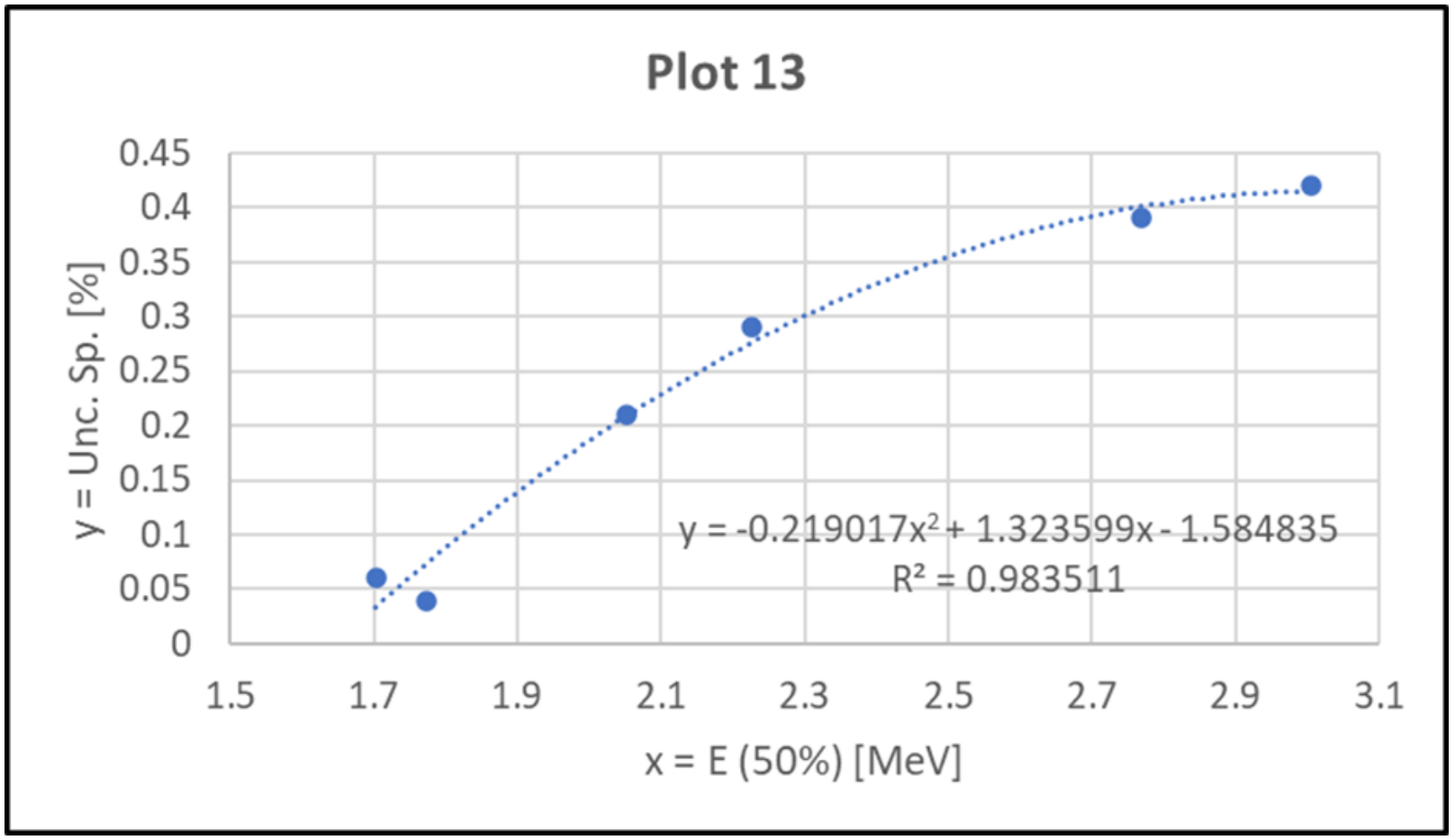
- These data agree very closely with a smooth fitted cubic polynomial.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II Neutron Inelastic Scattering Cross Sections



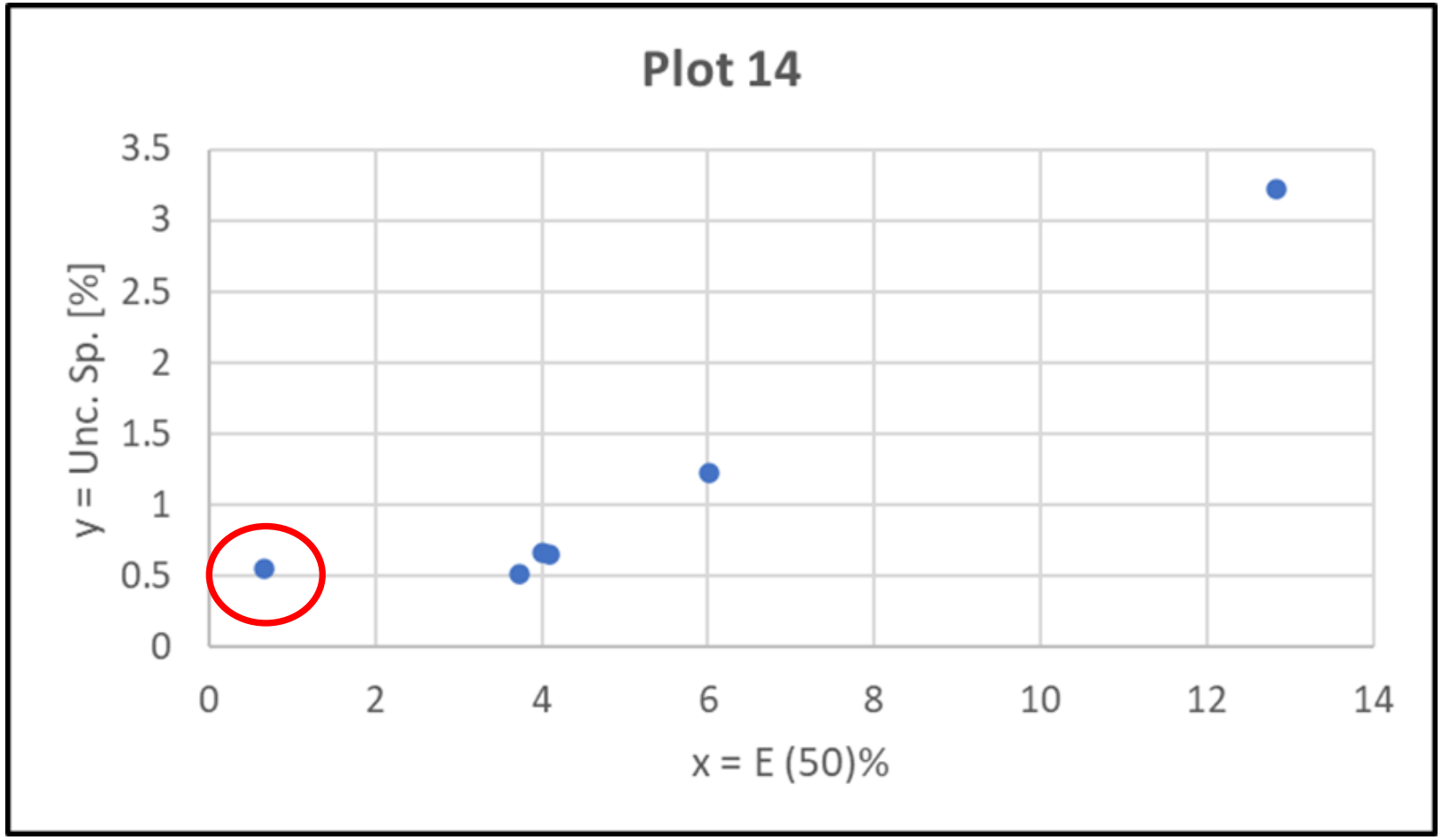
- These data agree reasonably well with a fitted straight line.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II Neutron Fission Cross Sections



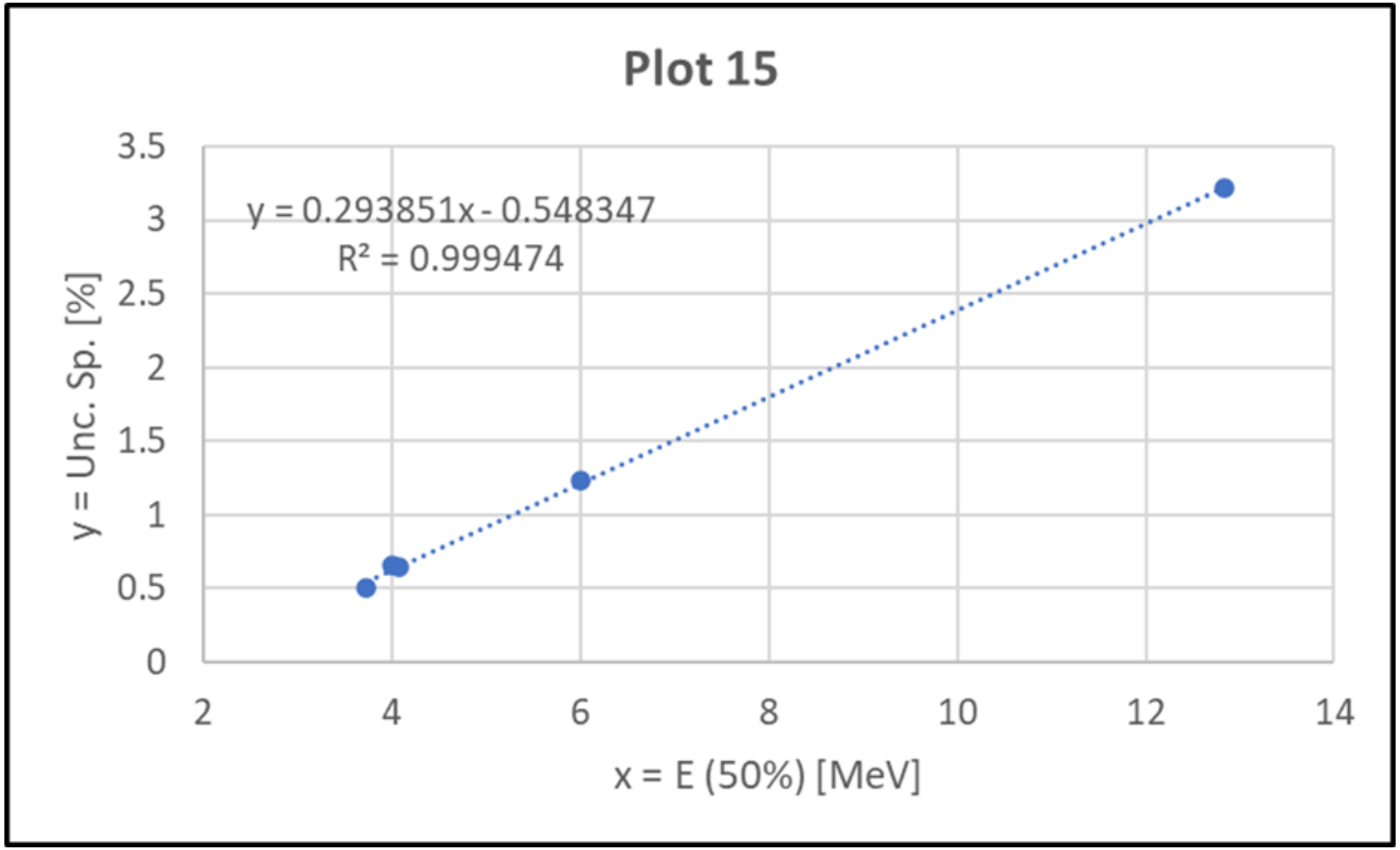
- These data agree reasonably well with a fitted quadratic polynomial. The uncertainties are small (< 1%).

SACS Cf-Spectrum Related Uncertainties for IRDFF-II (n,t) Cross Sections



- The “outlier” data point at E(50%) = 0.65 MeV corresponds to the 6Li(n,t)4He reaction.

SACS Cf-Spectrum Related Uncertainties for IRDFF-II (n,t) Cross Sections Minus the Data Point at E(50%) = 0.65 MeV



- These data agree quite well with a fitted straight line.

Summary and Conclusions

- The parameter E(50%) discussed in this presentation is useful for organizing SACS data.
- SACS uncertainties attributed to the 252Cf (s.f.) neutron fission spectrum for IRDFF-II cross sections range from near zero for E(50%) ≈ 2 MeV to 30% for E(50%) near 18 MeV.
- Systematic (and generally smoothly varying) increasing values of these uncertainties are observed for reactions with E(50%) > 2 MeV.
- Those uncertainties for reactions with E(50%) < 2 MeV tend to increase with decreasing values of E(50%), but vary less smoothly than do the reactions with E(50%) above 2 MeV. This is attributed mainly to structures in the cross sections in those reactions with small E(5)%). However, the uncertainties in this region are typically smaller than 1%.
- The observed regularities in the behavior of spectrum-related uncertainties vs. E(50%) for IRDFF-II reactions suggest that uncertainty estimates could be made for other reactions.

The End