Experimental data from a theoretical needs point of view

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NuWro * Wrocław Neutrino Event Generator *

T2K

Hyper-Kamiokande

UNIVERSITEIT GENT

Disclaimer

Outline

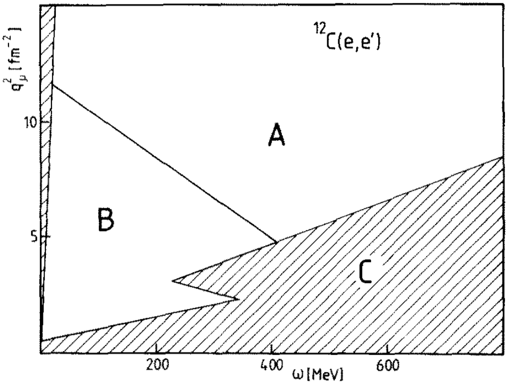
(1) Historical survey

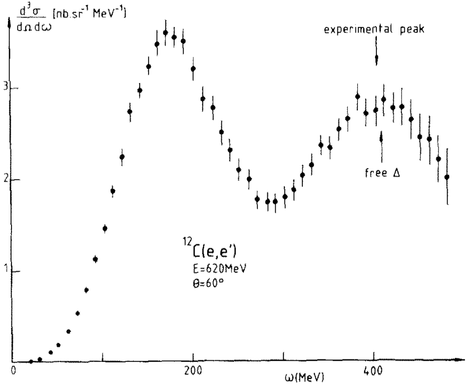
(2) Motivation for comparisons

(3) Practical overview

(4) Needs for future measurements

Historical survey

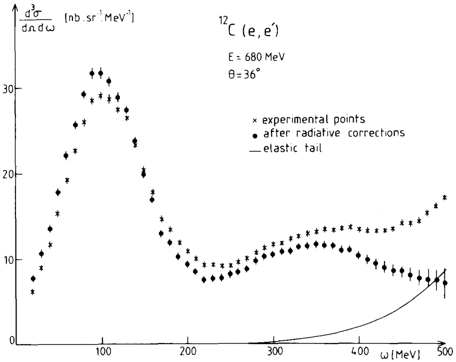


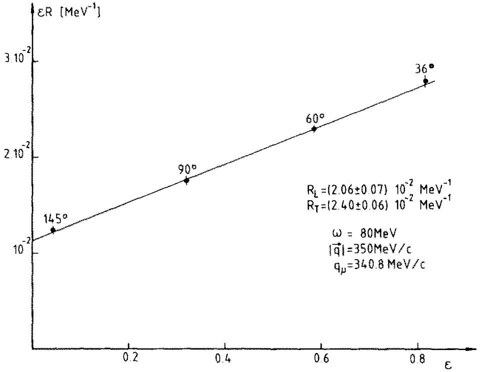


P. Barreau et al., Nucl.Phys.A 402 (1983) 515-540

→ Clear experimental conditions with **straightforward interpretation**

Historical survey

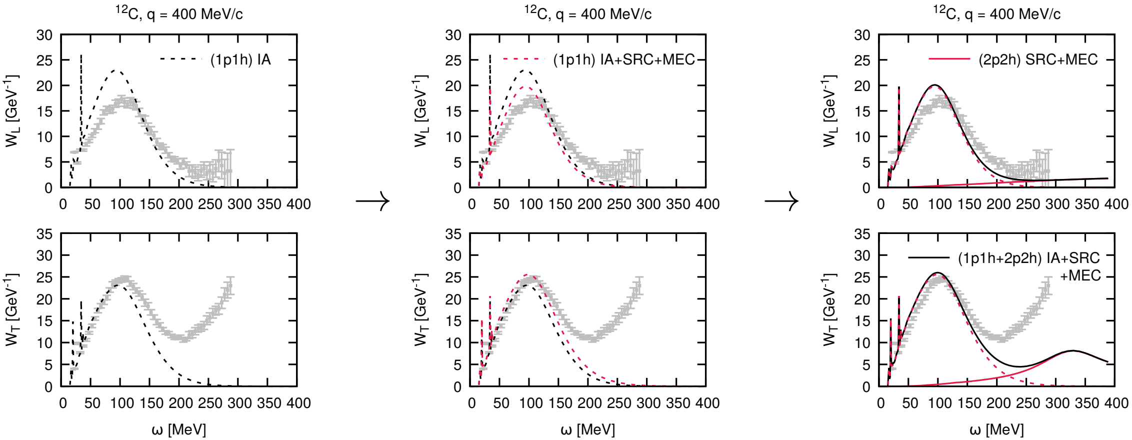




P. Barreau et al., Nucl.Phys.A 402 (1983) 515-540

→ Experimental analysis **resolved all ambiguities** and provided uncertainties

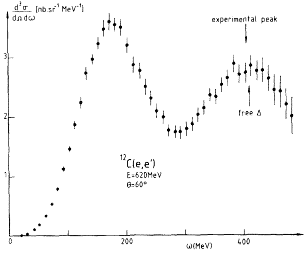
Historical survey



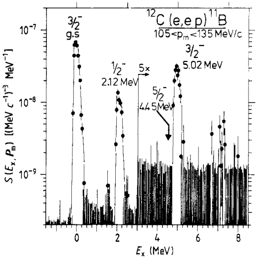
→ Comparing to these datasets is **intuitive and meaningful**

Historical survey

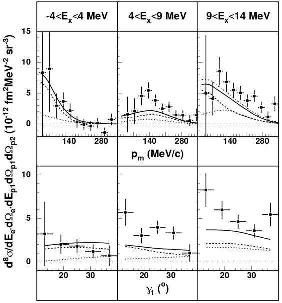
- Plenty of **useful datasets**: (e, e'); $(e, e'p)$; $(e, e'pp)$ ...



P. Barreau et al.,
Nucl.Phys.A 402 (1983) 515-540



P.K.A. de Witt Huberts,
J.Phys.G 16 (1990) 507-544



G.J.C Onderwater et al.,
Phys.Rev.Lett. 81 (1998) 2213-2216

- Clear experimental conditions with **straightforward interpretation**

◦ **Difficult access to datapoints**; relience on files of unknown origin or digitalization

◦ Sometimes detailed descriptions available only in printed papers or PhD theses

Noteable efforts in data perseverance

- Home page
- Data
- Table & Notes
- Utilities
- Bibliography
- Acknowledgements

!!!!!!!!!Change your Bookmark - see the new url above !!!!!!!!!!!!

Quasielastic Electron Nucleus Scattering Archive

Announcement - Just Added - August 2021: E08-014 from the paper, "Novel observation of isospin structure of short-range correlations in calcium isotopes" by D. Nguyen, Z. Ye at al. published in Phys.Rev.C 102 (2020) 6, 064004, e-Print: 2004.11448 [nucl-ex]

Announcement - June 2019: E12-14-012 (Dai:2018) data now available

Welcome to Quasielastic Electron Nucleus Scattering Archive

In connection with a review article (Quasielastic Electron-Nucleus Scattering, by O. Benhar, D. Day and I. Sick) published in the Reviews of Modern Physics [Rev. Mod. Phys. 80, 189-224, 2008], we have collected here an extensive set of quasielastic electron scattering data in order to preserve and make available these data to the nuclear physics community.

We have chosen to provide the cross section only and not the separated response functions. Unless explicitly indicated the data do not include Coulomb corrections.

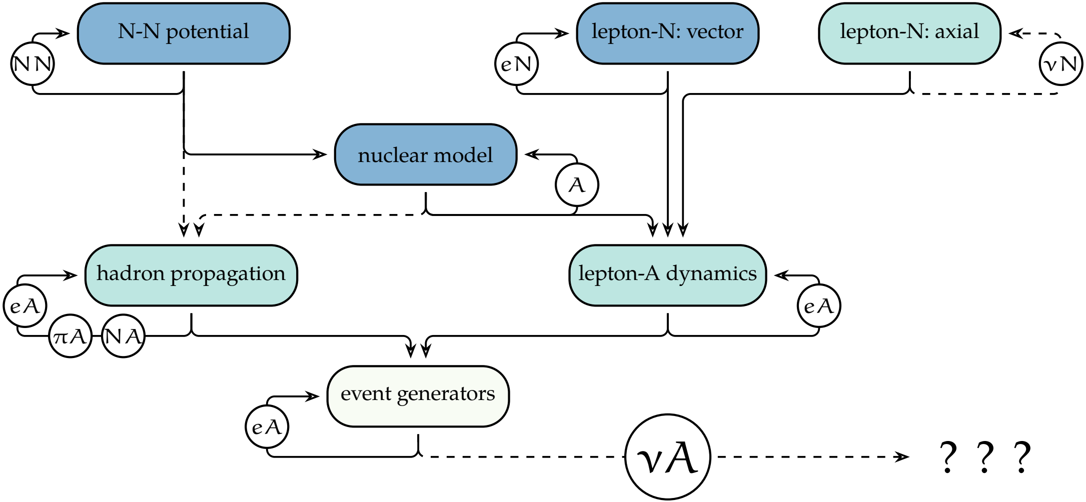
Our criteria for inclusion into the data base is the following:

1. Data published in tabular form in journal, thesis or preprint.
2. Radiative corrections applied to data.
3. No known or acknowledged pathologies

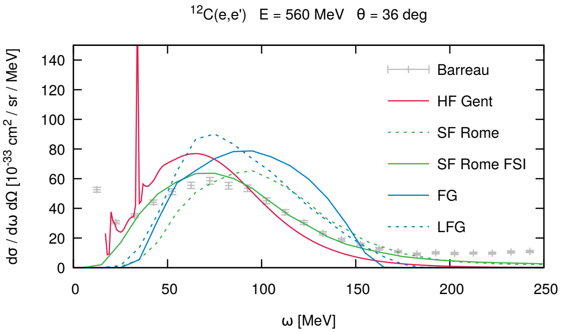
At present there are about 600 different combinations of targets, energies and angles consisting of some 19,000 data points.

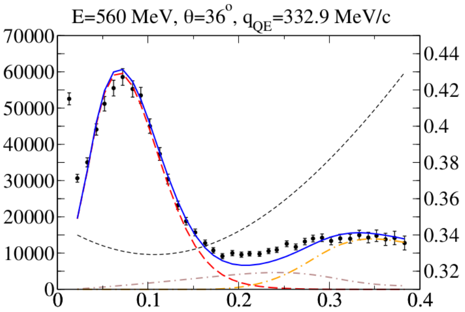
Donal Day et al., arXiv:nucl-ex/0603032

Motivation for comparisons



Example

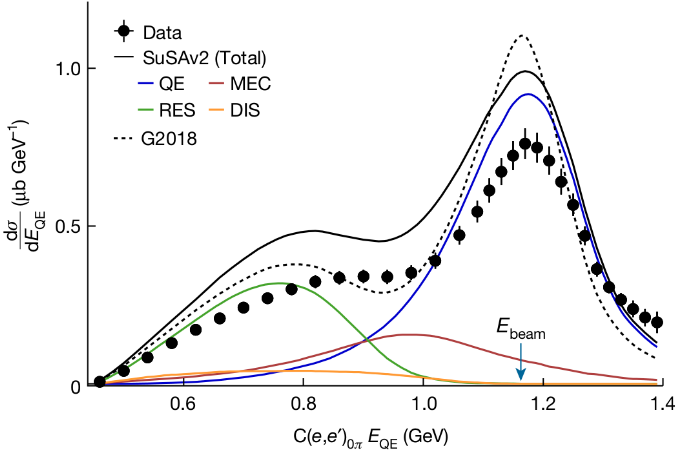




Phys.Rev.D 94 (2016) 013012

→ In inclusive electron scattering SuSAv2 (RMF-based) is a **more complete model** than (L)FG

Example



Nature 599 (2021) 565-570

→ **Generators do not compare well**; G18_10a_02_11 seems to be better

Example

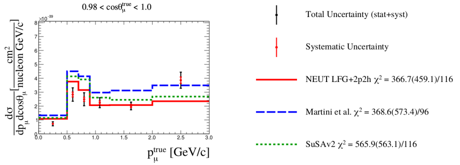


FIG. 20. Measured ν_μ CC-0π double-differential cross-section per nucleon in bins of true muon kinematics with systematic uncertainty (red bars) and total (stat.+syst.) uncertainty (black bars). The results are compared to NEUT version `5.4.1`, which uses an LFG+RPA model with 2p2h (solid red line), Martini *et al.* (dashed blue line) and SuSAv2 (green dashed line) models. The full and shape-only (in parenthesis) $\chi 2$ are reported. The last bin in momentum is not displayed for readability.

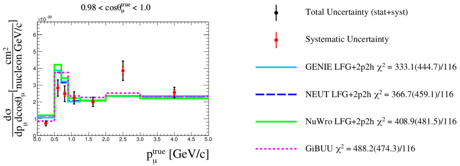


FIG. 25. Measured ν_μ CC-0π double-differential cross-section per nucleon in bins of true muon kinematics with systematic uncertainty (red bars) and total (stat.+syst.) uncertainty (black bars). The result is compared with NEUT (dashed blue line), NuWro version `18.02.1` (green solid line) and GiBUU `2019` (pink dotted line) prediction. All generators use an LFG+RPA model that includes 2p2h. The full and shape-only (in parenthesis) $\chi 2$ are reported. The last bin in momentum is not displayed for readability.

Phys.Rev.D 101 (2020) 112001

What can we learn from modern data?

- The ultimate goal of any comparisons should be drawing **physics conclusions**
- The **theoretical perspective is ignorant** of the statistical methodology
- In the omniscient case:
  - Comprehensive **exclusive electron measurements** could constrain

    $\rightarrow$ vector part of interactions, lepton-nucleus dynamics, generators...
  - High statistics **neutrino measurements** could constrain

    $\rightarrow$ axial part of interactions, subtilities of in-medium weak interactions...

Q: **Will we meet at the some point somewhere in the future?**

What do we expect the endgame to look like?

Practical overview

To prepare a data comparison, we need:

Flux predictions	→	**reliable**
Final state topology	→	**unambiguous**
Relevant interaction dynamics	→	**meaningful**
Varibles reconstruction	→	**clear**
Data points	→	**physical**

Flux predictions

- It is essential to compare using the **same neutrino energy distribution**

e.g. T2K had a number of flux evaluation analyses (2020, 2016, 2013...)
→ all of them are **well-documented** and **available on the website**
→ some data releases **explicitly contain txt files** [Phys.Rev.D 98 (2018) 012004]

- Many neutrino flux files appear from **unverified sources**

e.g. NuWro has a number of flux files without proper documentation
→ especially problematic for older experiments

Q: **Should we incorporate more details of the flux predictions?**

How will this be resolved for analyses using the "PRISM-like" fluxes?

Final state topology

- We need to make our best to **compare apples with apples**

e.g. Usage of topologies like CC0π is a **great progress in the community**
$\rightarrow$ we are not relying on model-dependent pion absorption anymore
$\rightarrow$ but what is the treshold on the 0π in the final state?

- Experimental results always involve certain **acceptances**

e.g. Even sophisticated 4π detectors have angular dead zones
$\rightarrow$ seems to be impossible to compare without a detector simulation?

Q: **Is it possible to publish results with a complete event selection know-how?**

Can we ensure that the published data have long-term viability?

Variables reconstruction

- The **unfolding procedure is inevitable** while performing neutrino measurements

e.g. This whole workshop :)

- ∘ Experimental results sometimes involve **cuts on reconstructed variables**

e.g. MINERvA CC1π^+ results involve Q^2_{rec} and $W_{\mathsf{rec}} < 1.4$ [Phys.Rev.D 92 (2015) 092008]
$\rightarrow$ the obtained results are affected drastically

Q: **How can we draw physical conclusions on reconstructed variables?**

How can we be sure that this is not model-dependent?

Will increasing the statistics solve majority of our problems?

Data points

- **Data releases** are the main source of acquiring modern measurements

e.g. Data is usually released in the **ROOT format**
$\rightarrow$ **theoreticians do not use ROOT**
$\rightarrow$ this forces us to write special scripts to extract a few datapoints
$\rightarrow$ extracting more sophisticated information is troublesome

Q: **Is it possible to always provide data in a txt-like file?**

How will we manage this once we approach multi-dimensional data?

Is is possible to provide scripts providing minimal working examples?

Conclusions

The idealized data release could contain a **complete working example**:

→ Neutrino flux as a txt file

→ A precise description of the experimental topology

→ Procedures allowing to compare to data without additional assumptions

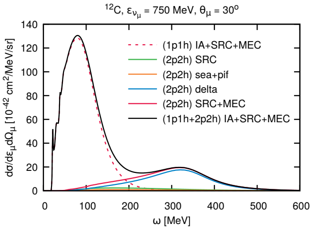
→ Data points in an easily accessible format

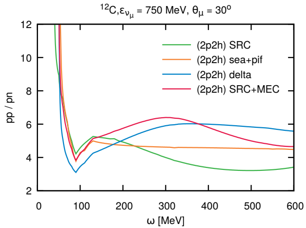
→ Example scripts generating plots as intended by the author

Q: **This is a greedy list. What is the compromise?**

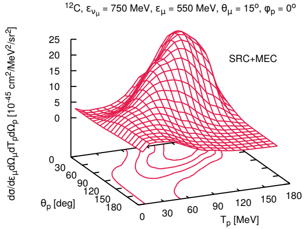
Needs for future measurements

Inclusive one- and two-nucleon knock-out





Semi-inclusive two-nucleon knock-out



Exclusive two-nucleon knock-out