

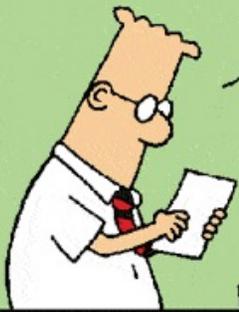
Data Visualization

Lawrence Weinstein
Old Dominion University

With thanks to Edward Tufte, a pioneer in the field.
https://www.edwardtufte.com/tufte/books_vdqi

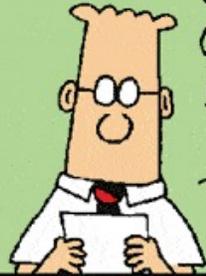
The Origin of Bad Graphics

THIS NEXT TRANSPARENCY IS AN INCOMPREHENSIBLE JUMBLE OF COMPLEXITY AND UNDEFINED ACRONYMS.



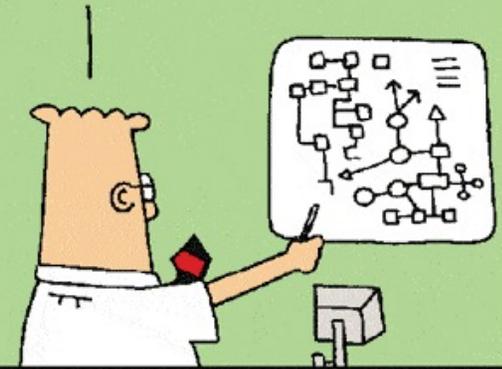
S. ADAMS E-mail: SCOTTADAMS@AOL.COM

YOU MIGHT WONDER WHY I'M GOING TO SHOW IT TO YOU SINCE THE ONLY POSSIBLE RESULT IS TO LOWER YOUR OPINION OF MY COMMUNICATION SKILLS.



1/1/11 © 1995 United Feature Syndicate, Inc. (NYC)

FRANKLY, IT'S BECAUSE I LIKE MAKING COMPLEX PICTURES MORE THAN I LIKE YOU.



Why are you showing the data?

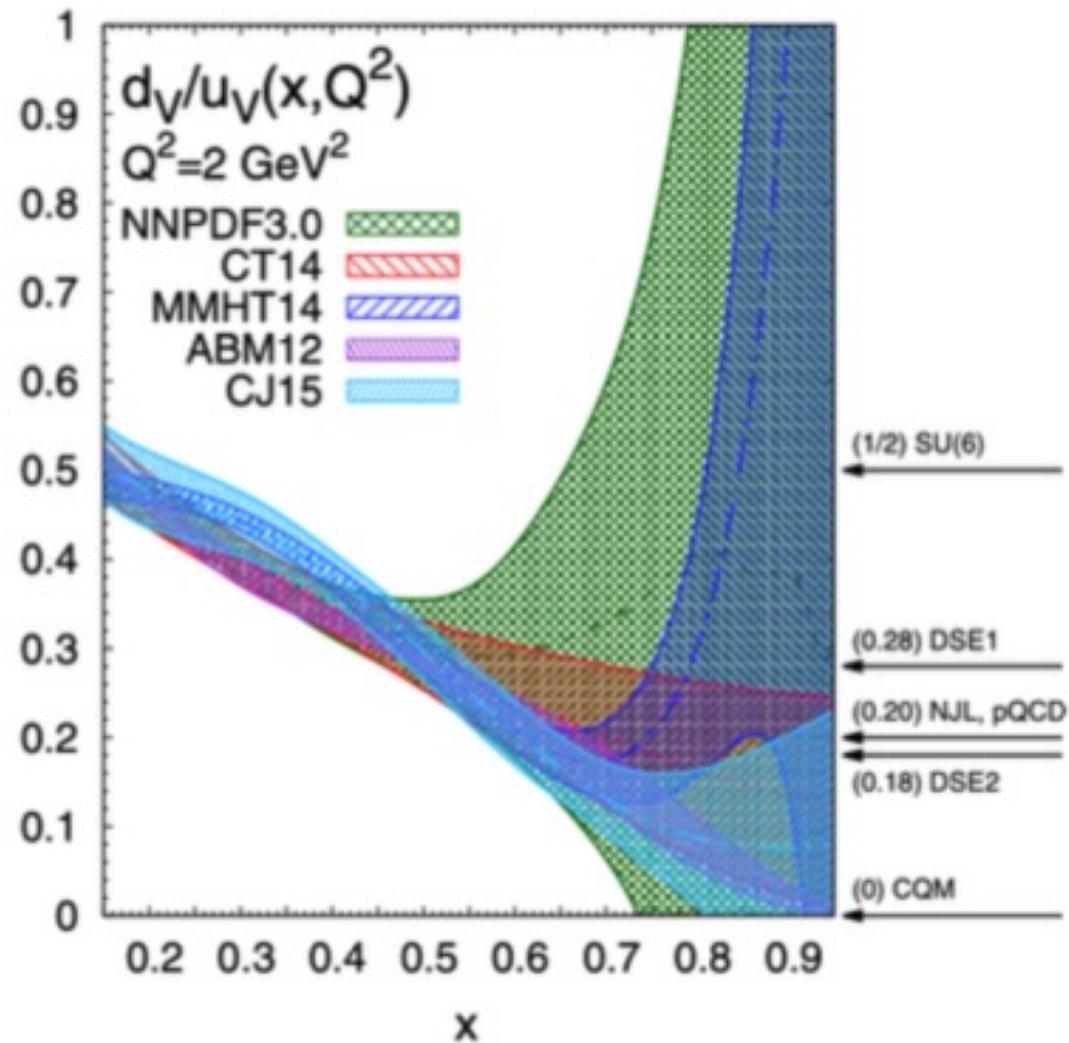
- To impress people with
 - the amount of data you took
 - how smart you are
 - how many symbols you can cram into a graphic

Why are you showing the data?

- ~~• To impress people with
 - ~~• the amount of data you took~~
 - ~~• how smart you are~~
 - ~~• how many symbols you can cram into a graphic~~~~
- To persuade people
 - To adopt your theory / data interpretation
 - To hire you
 - To approve your experiment
 - To make a decision

Make easy to understand plots.

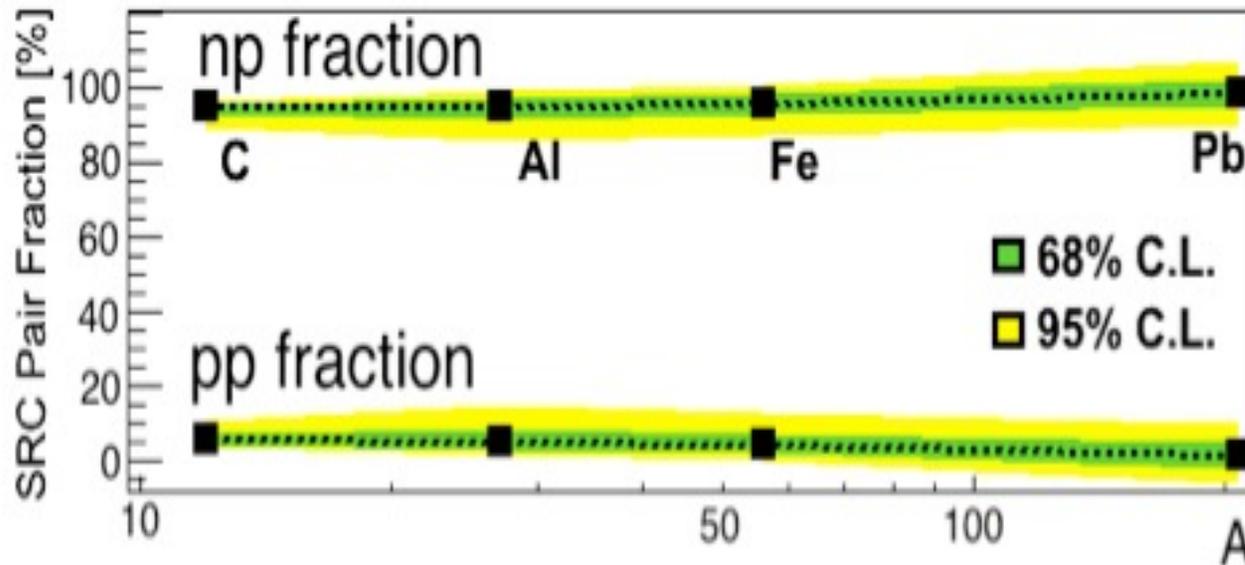
Is this a good plot?



Eur. Phys. J. C (2016) 76:383

What's the money plot?

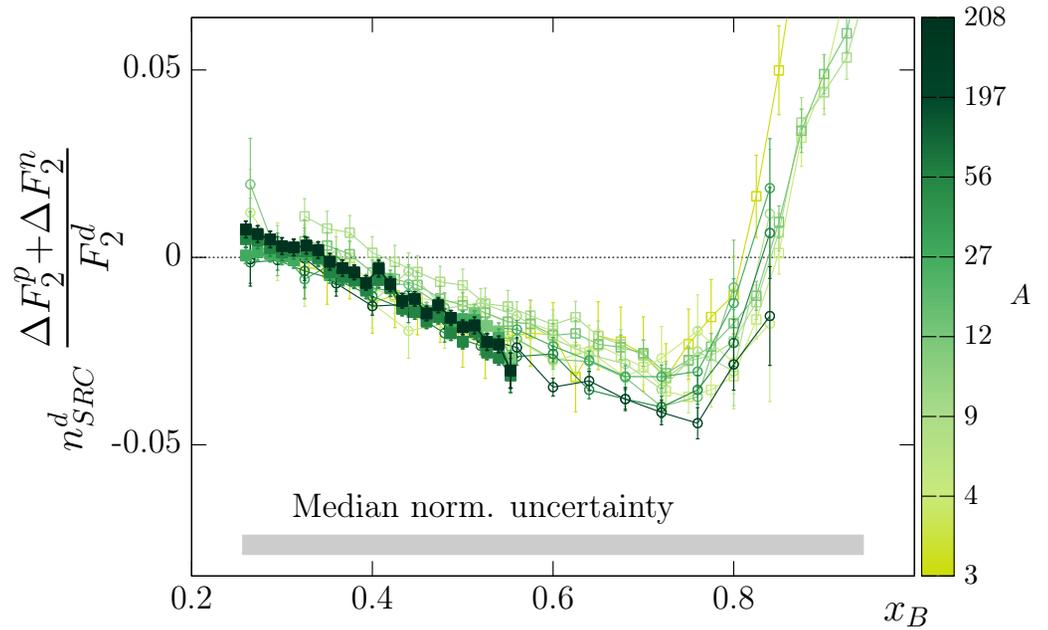
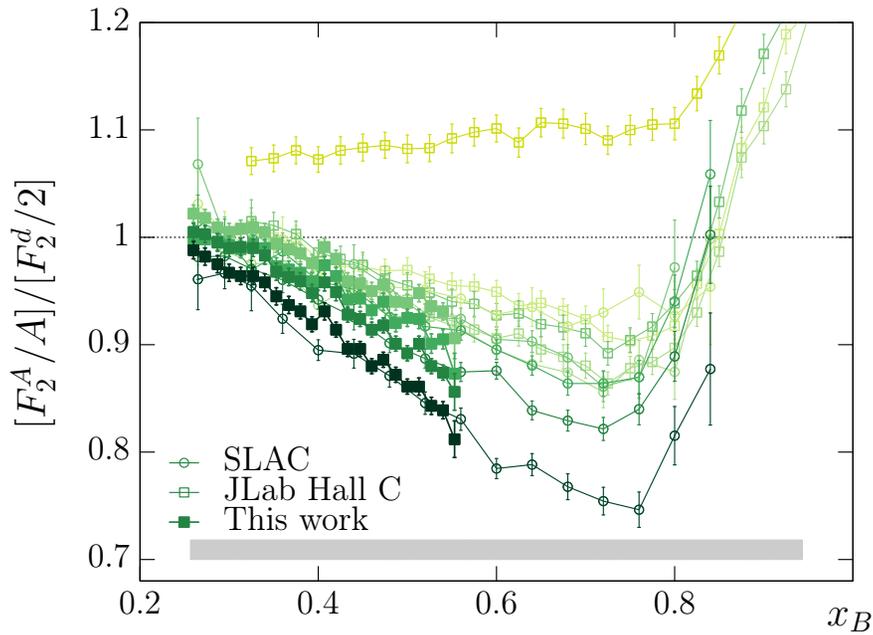
What's the money plot?



Science 346 (2014) 614

Message: Lots more of these than those.

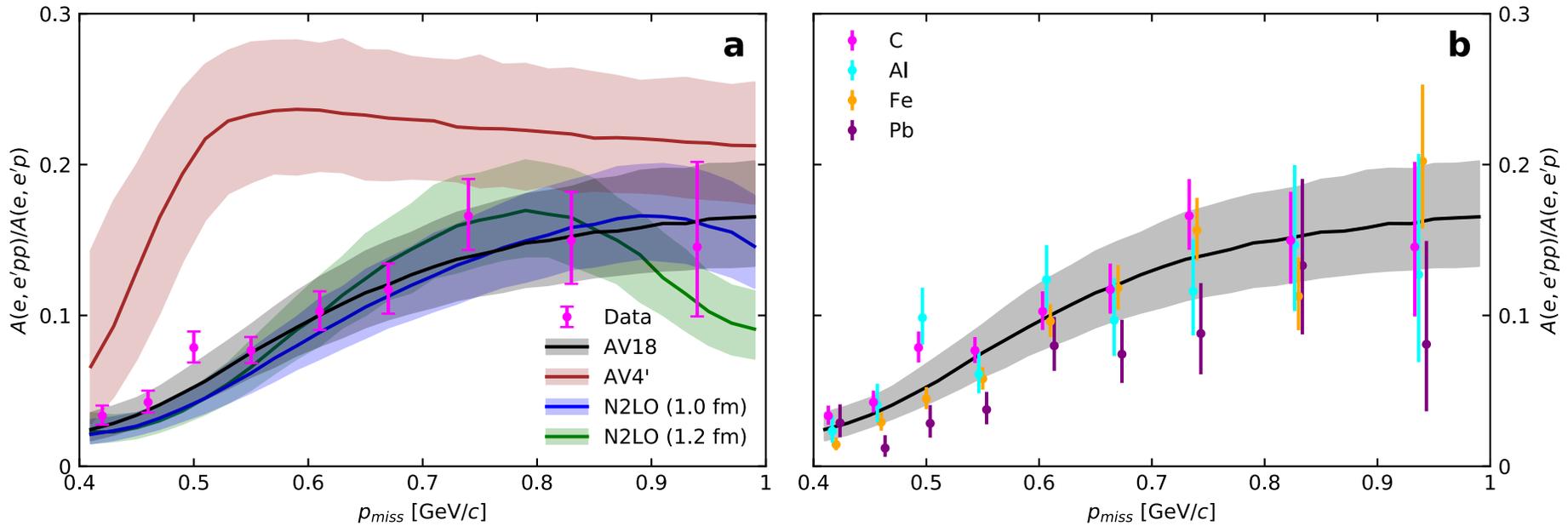
What's the money plot?



Nature **566** (2019) 354

Message: We can make all that data line up!

What's the money plot?



Nature 578 (2020) 540

Message:

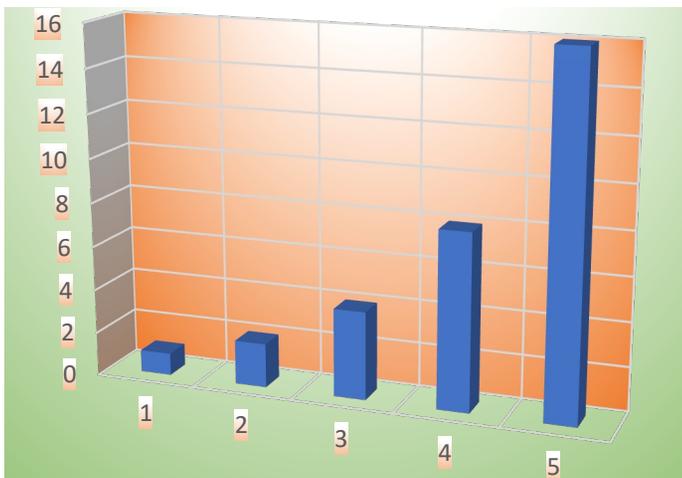
(a) This changes as the x-value increases – (b) it's the same for all nuclei

Eliminate Chart Junk

Unnecessary

- **fonts**
- **COLORS**
- **Backgrounds**
- *Ornaments* (ornamentation)

Chart Title



Eliminate Chart Junk

Unnecessary

- **fonts**
- **COLORS**
- **Backgrounds**
- *Ornaments* (ornamentation)

Chart Title

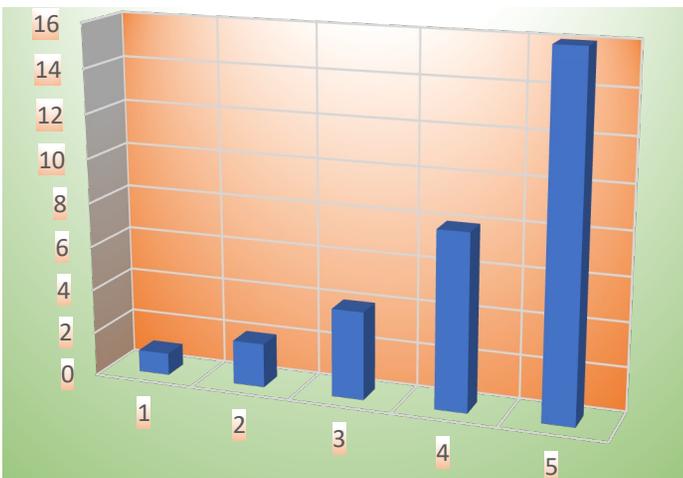
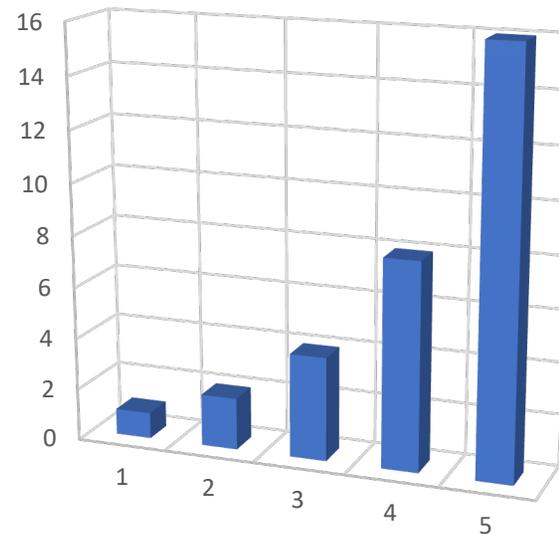


Chart Title



Eliminate Chart Junk

Unnecessary

- **fonts**
- **COLORS**
- **Backgrounds**
- *Ornaments* (ornamentation)

Chart Title

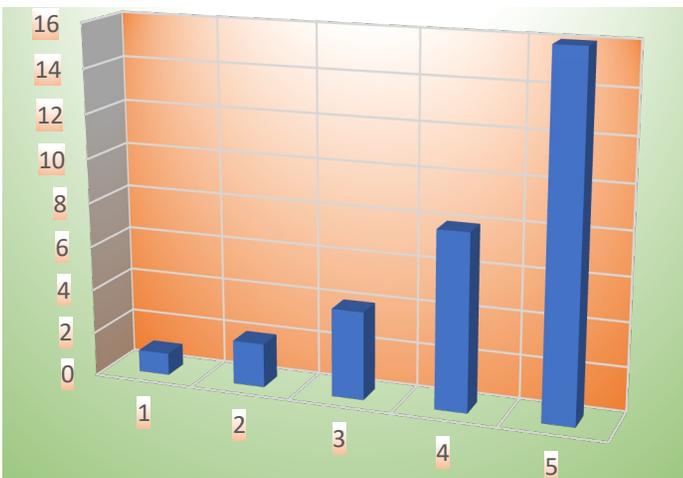


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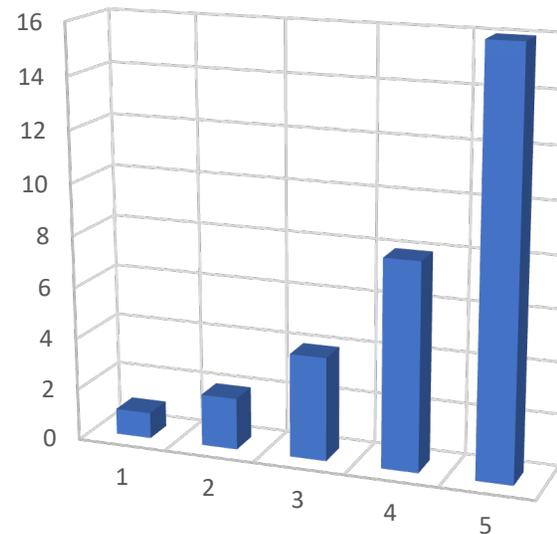
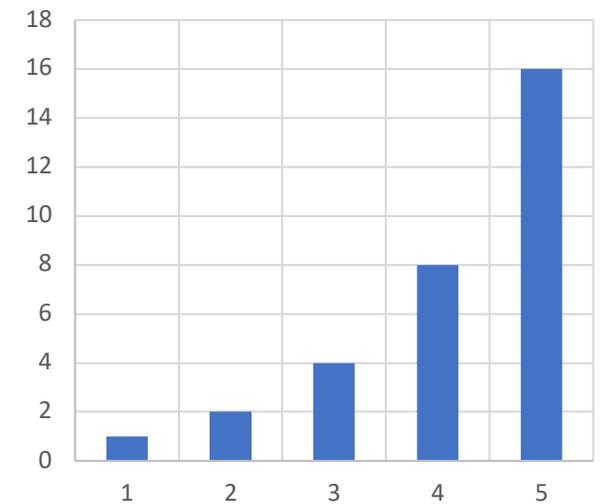
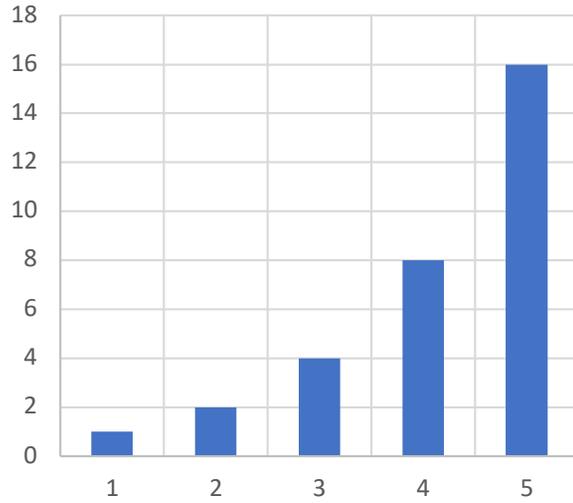


Chart Title



Maximize data-ink ratio

Chart Title



Maximize data-ink ratio

Chart Title

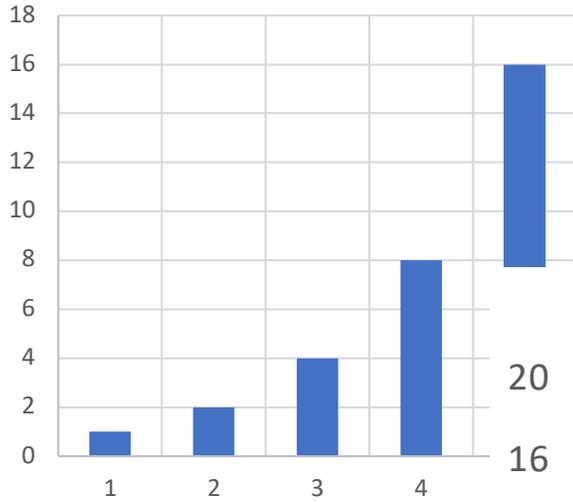
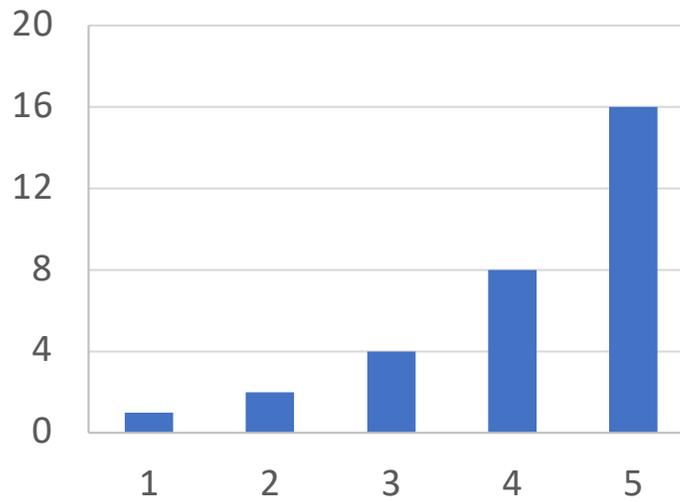


Chart Title



Maximize data-ink ratio

Chart Title

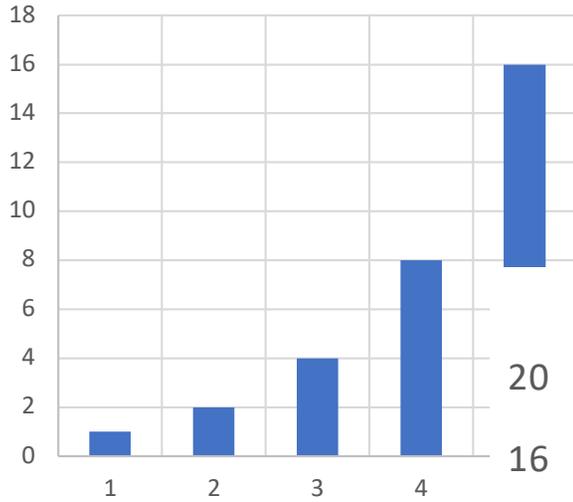


Chart Title

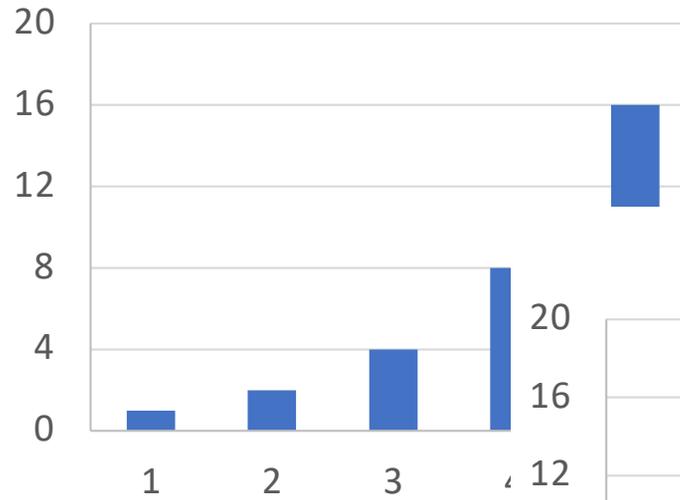
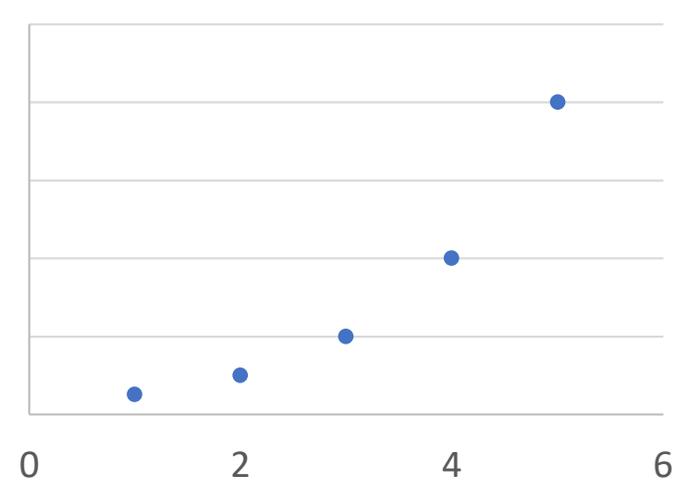
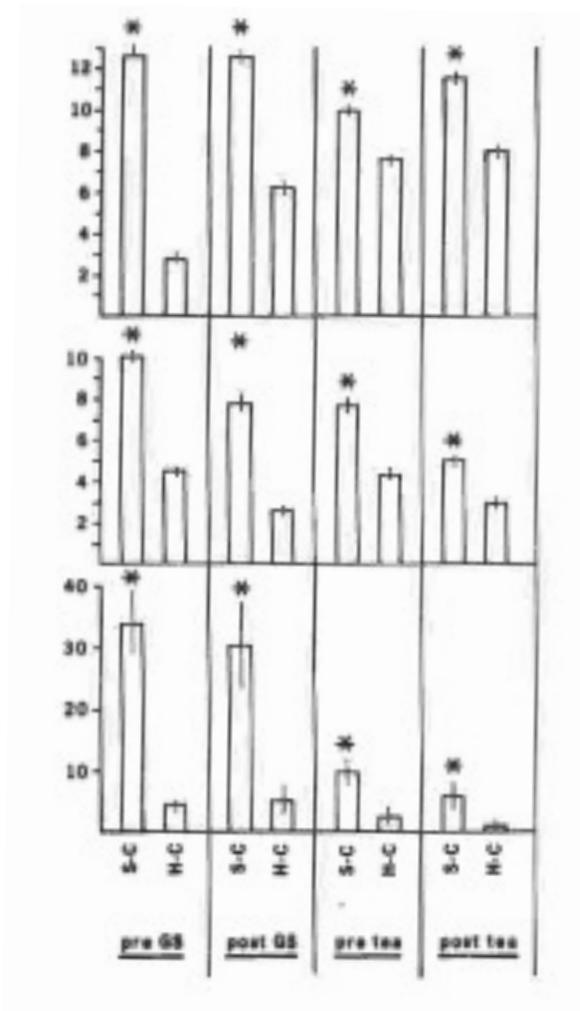


Chart Title



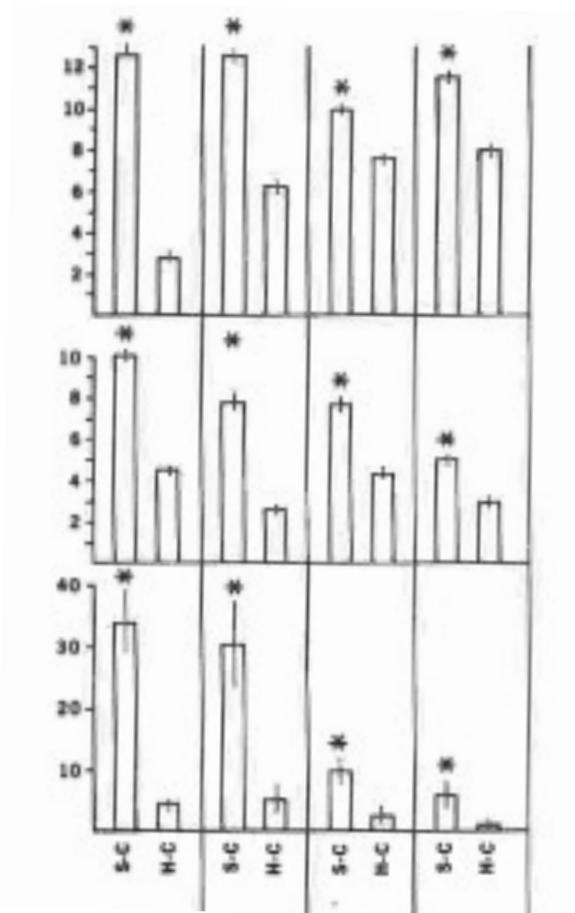
Maximize data-ink ratio



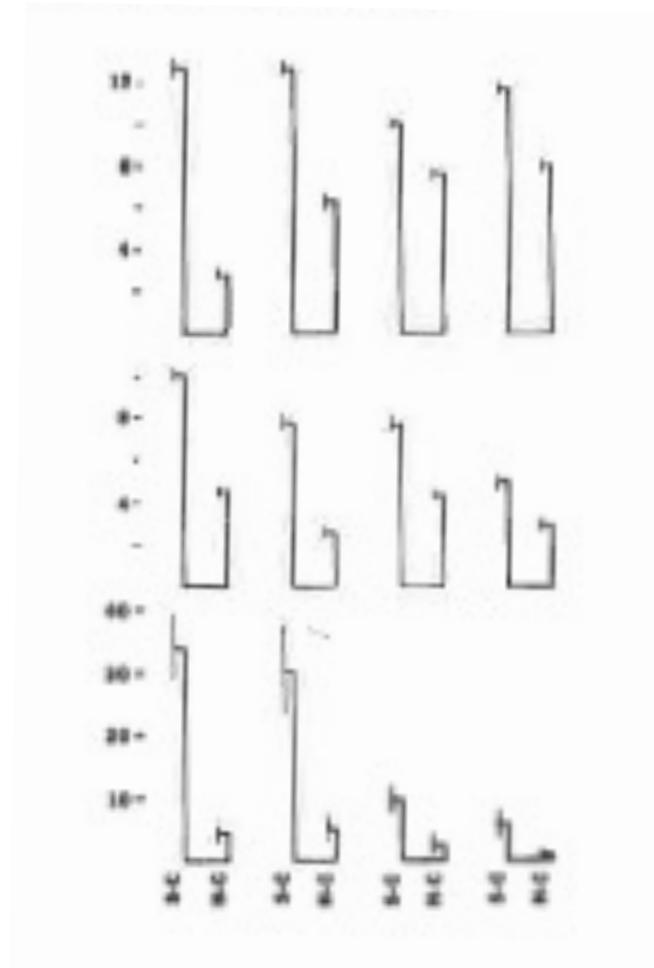
Comparing the left and right bars in each panel

Edward Tufte, "The Visual Display of Quantitative Information"

Maximize data-ink ratio

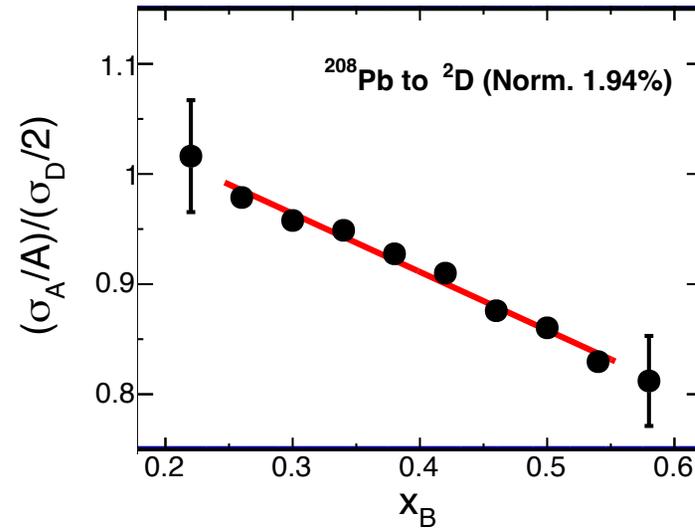
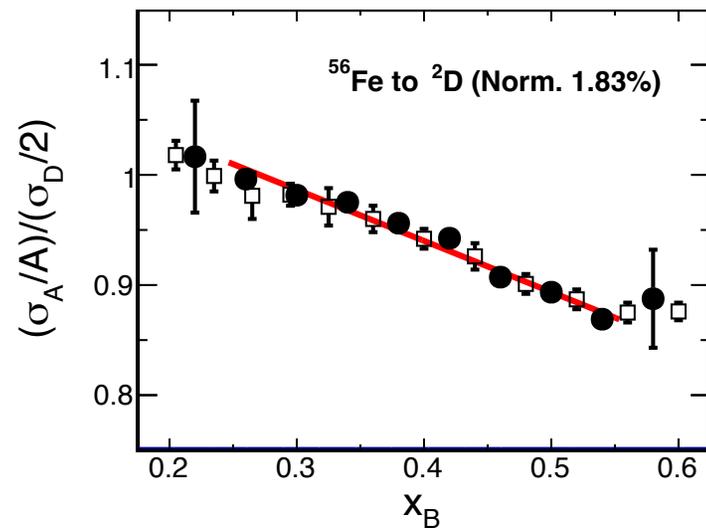
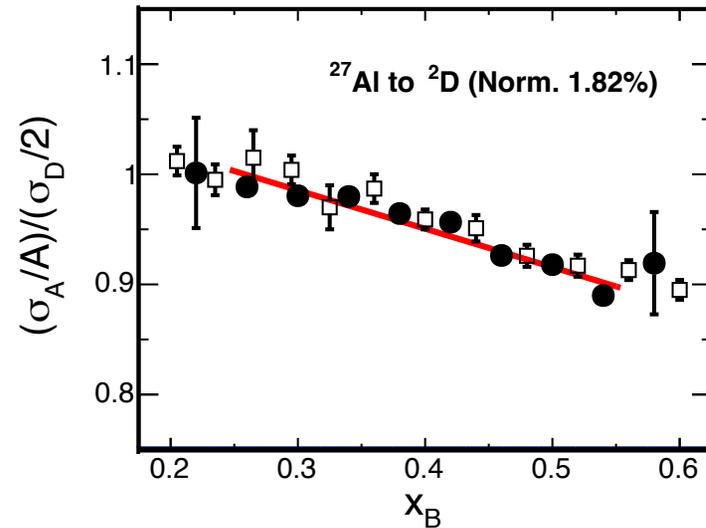
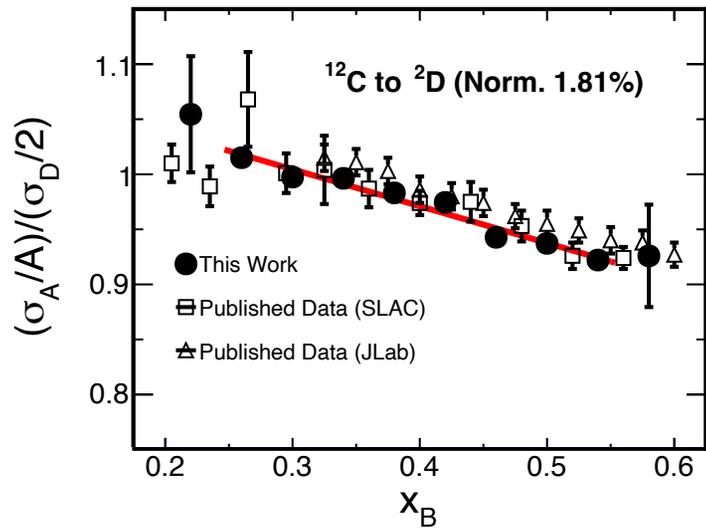


Comparing the left and right bars in each panel

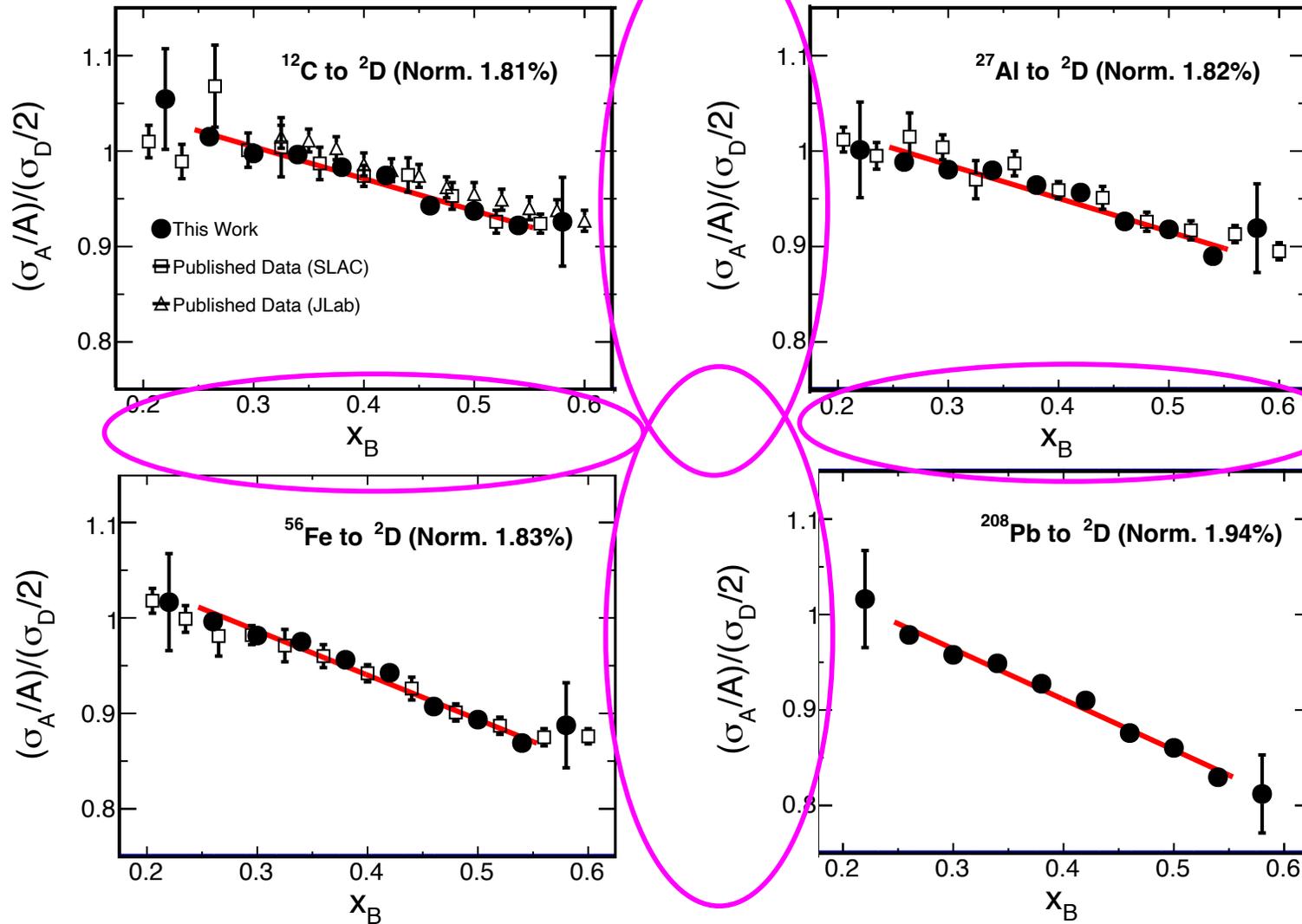


Edward Tufte, "The Visual Display of Quantitative Information"

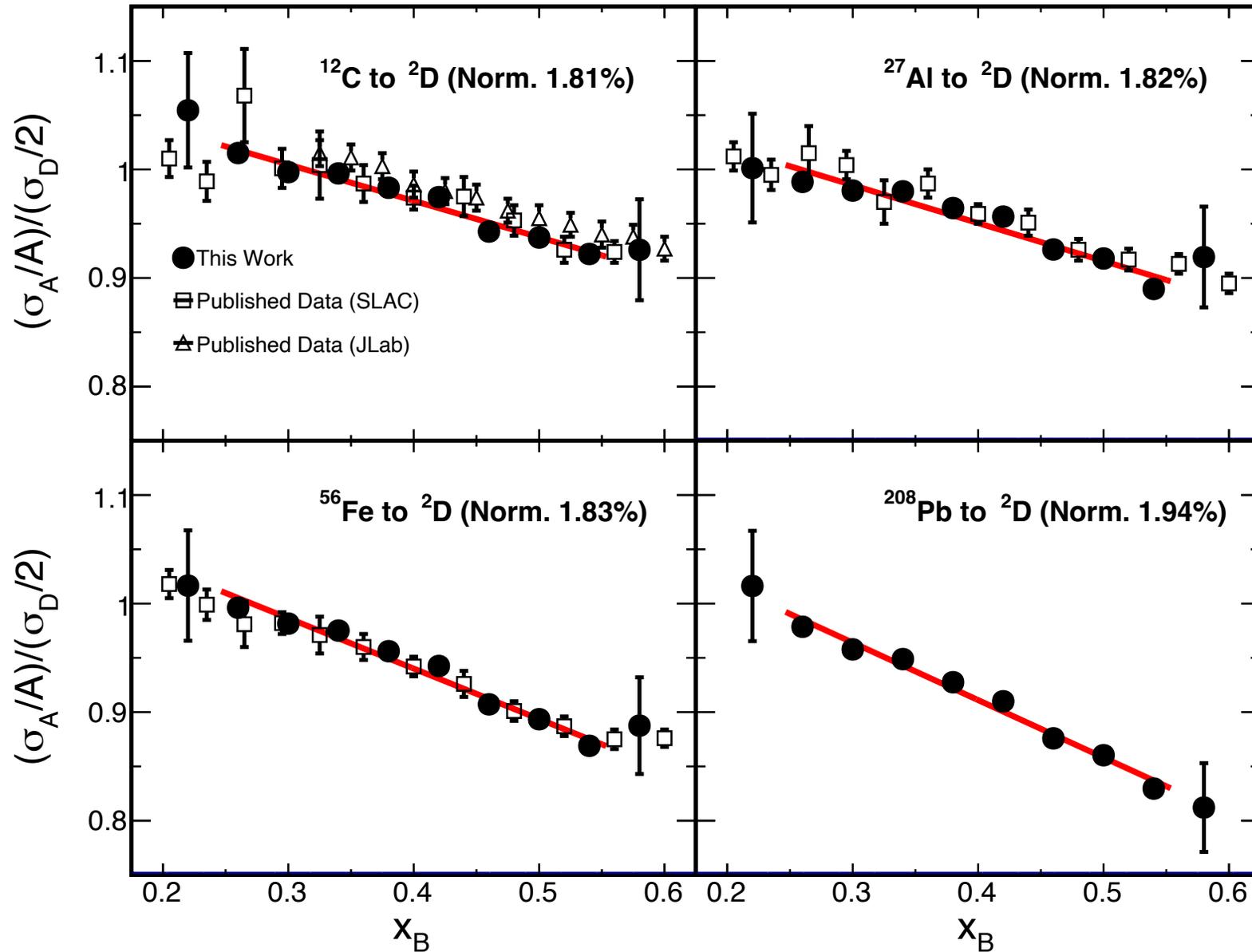
Maximize data-ink ratio



Maximize data-ink ratio



Maximize data-ink ratio

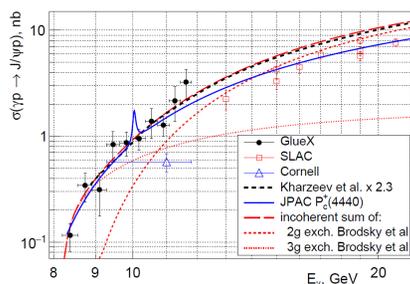


Don't waste space

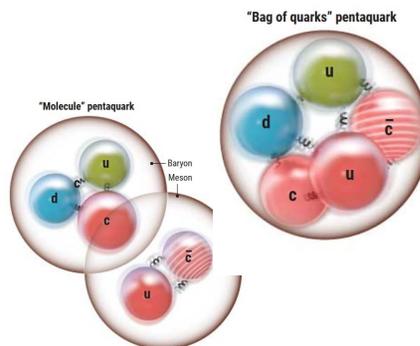
Pentaquark Searches

GLUEX

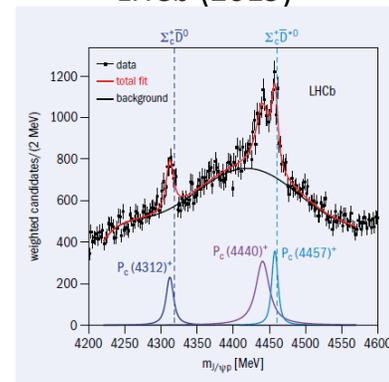
$$\gamma p \rightarrow P_c \rightarrow J/\psi p$$



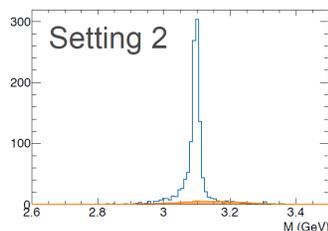
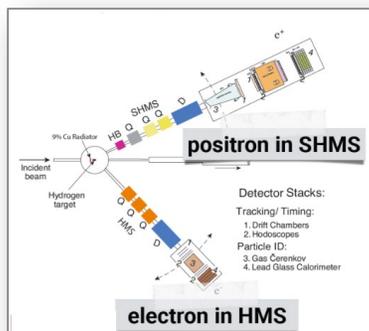
Published in PRL
(Note: 27% normalization uncertainty)



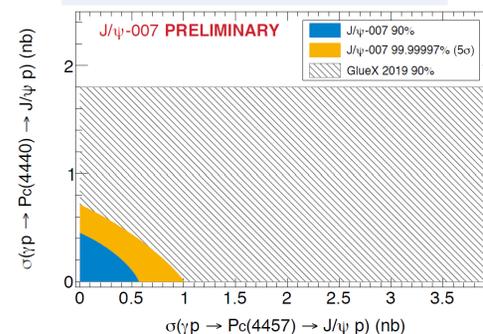
LHCb (2019)



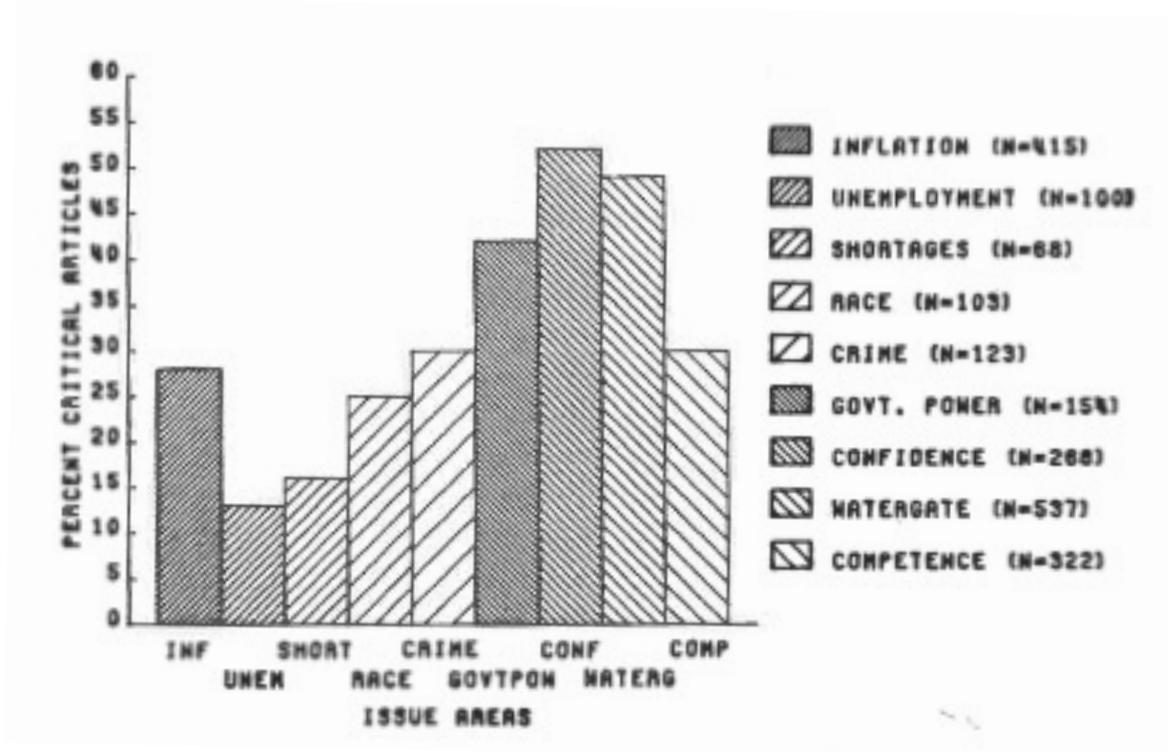
Hall C



- ~8x published GlueX data
- Presented at GHP2021



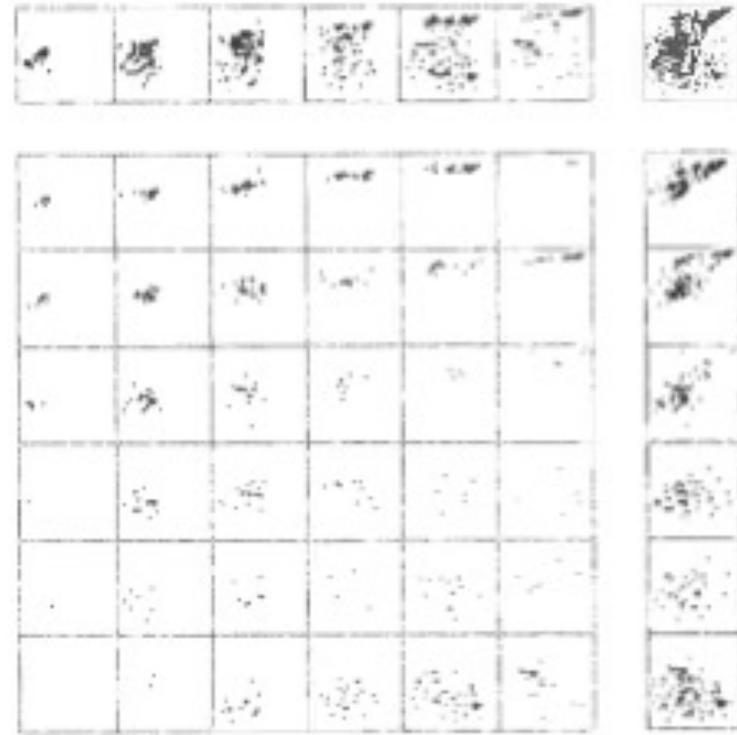
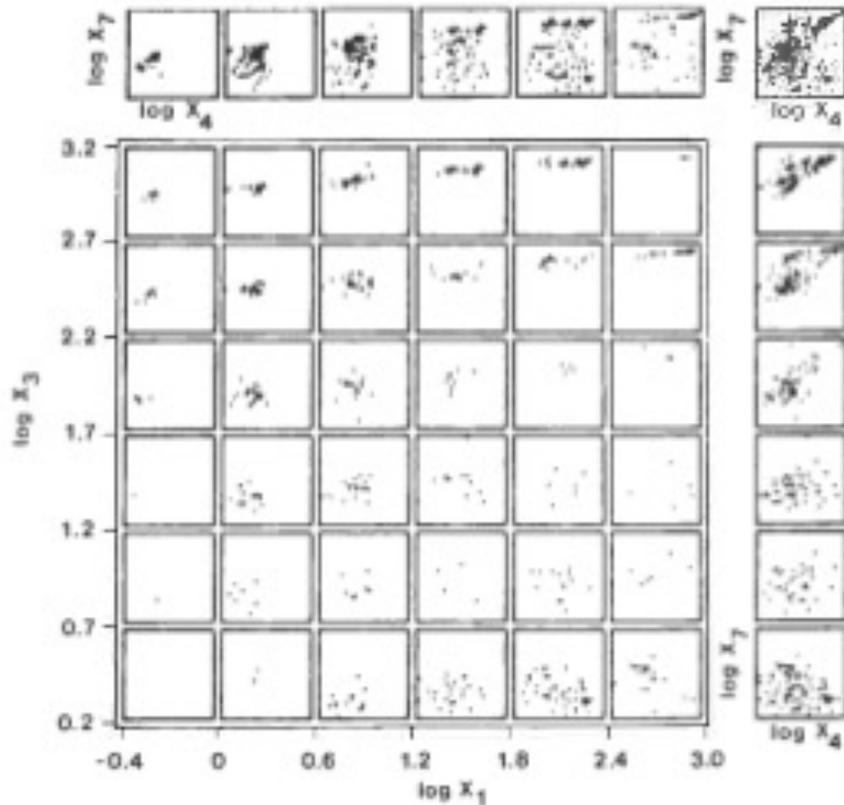
Avoid Distractions



Edward Tufte, "The Visual Display of Quantitative Information"

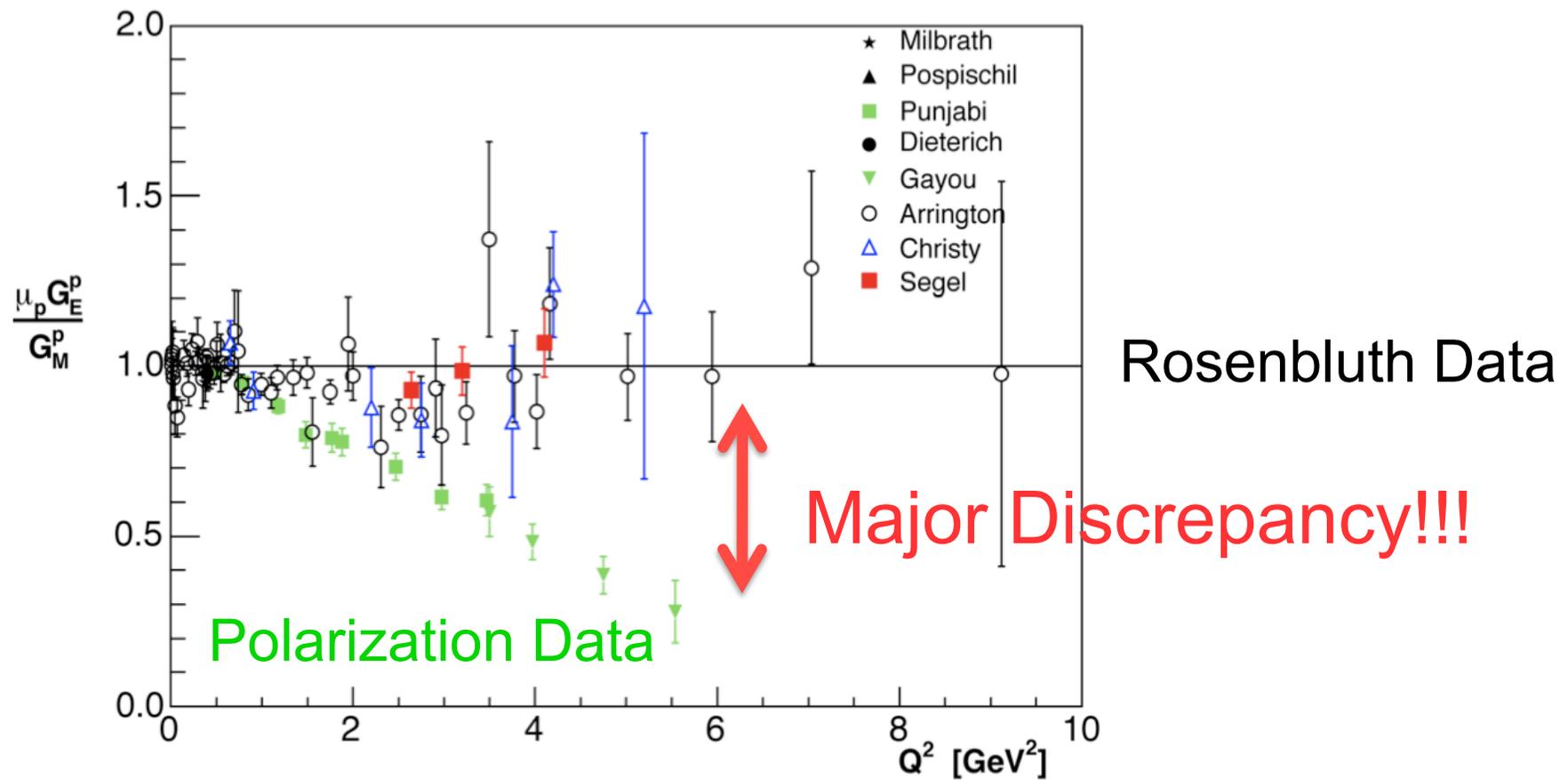
Data/Ink + Distractions

MULTIWINDOW PLOT OF PARTICLE PHYSICS MOMENTUM DATA

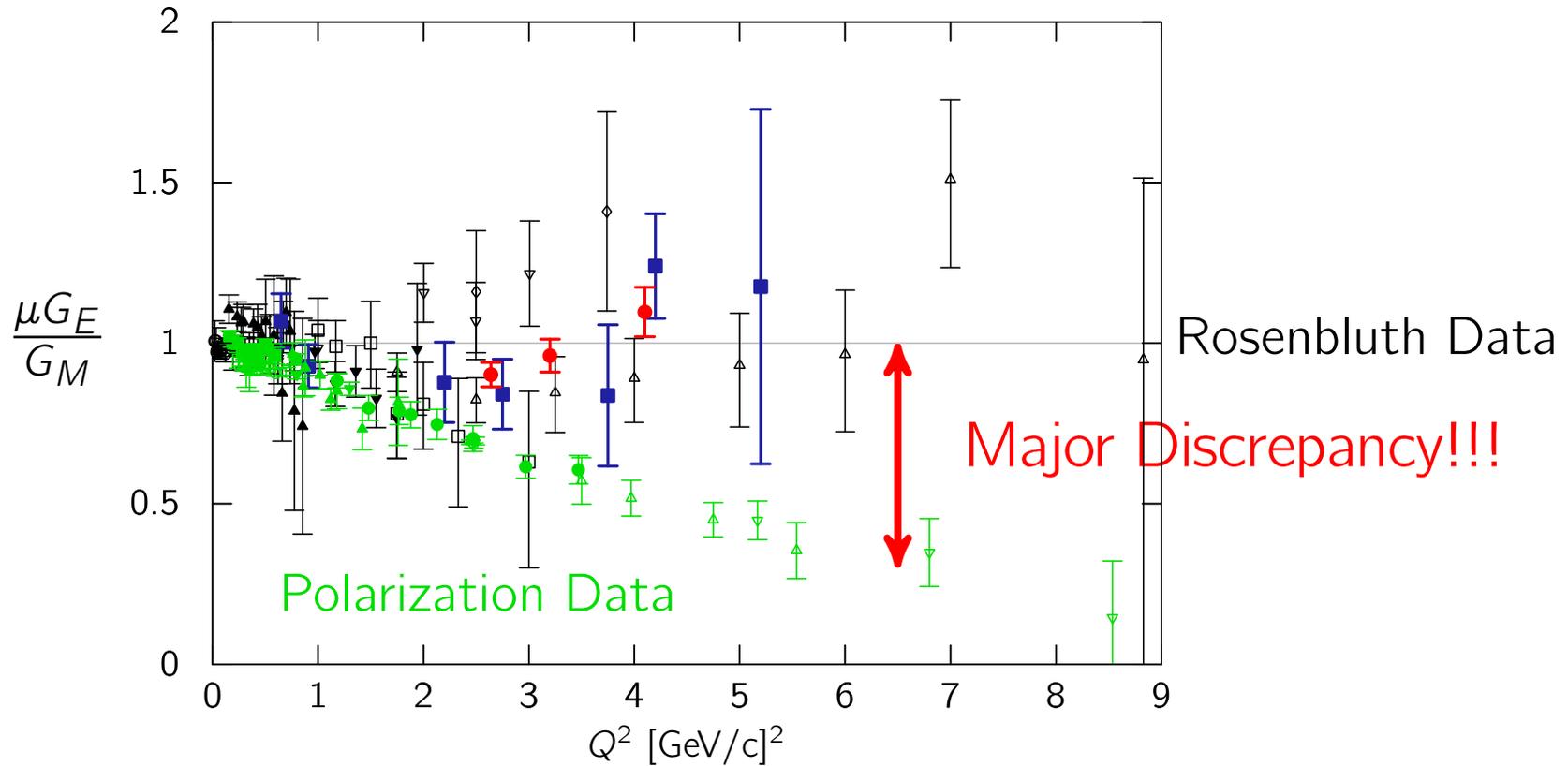


Edward Tufte, "The Visual Display of Quantitative Information"

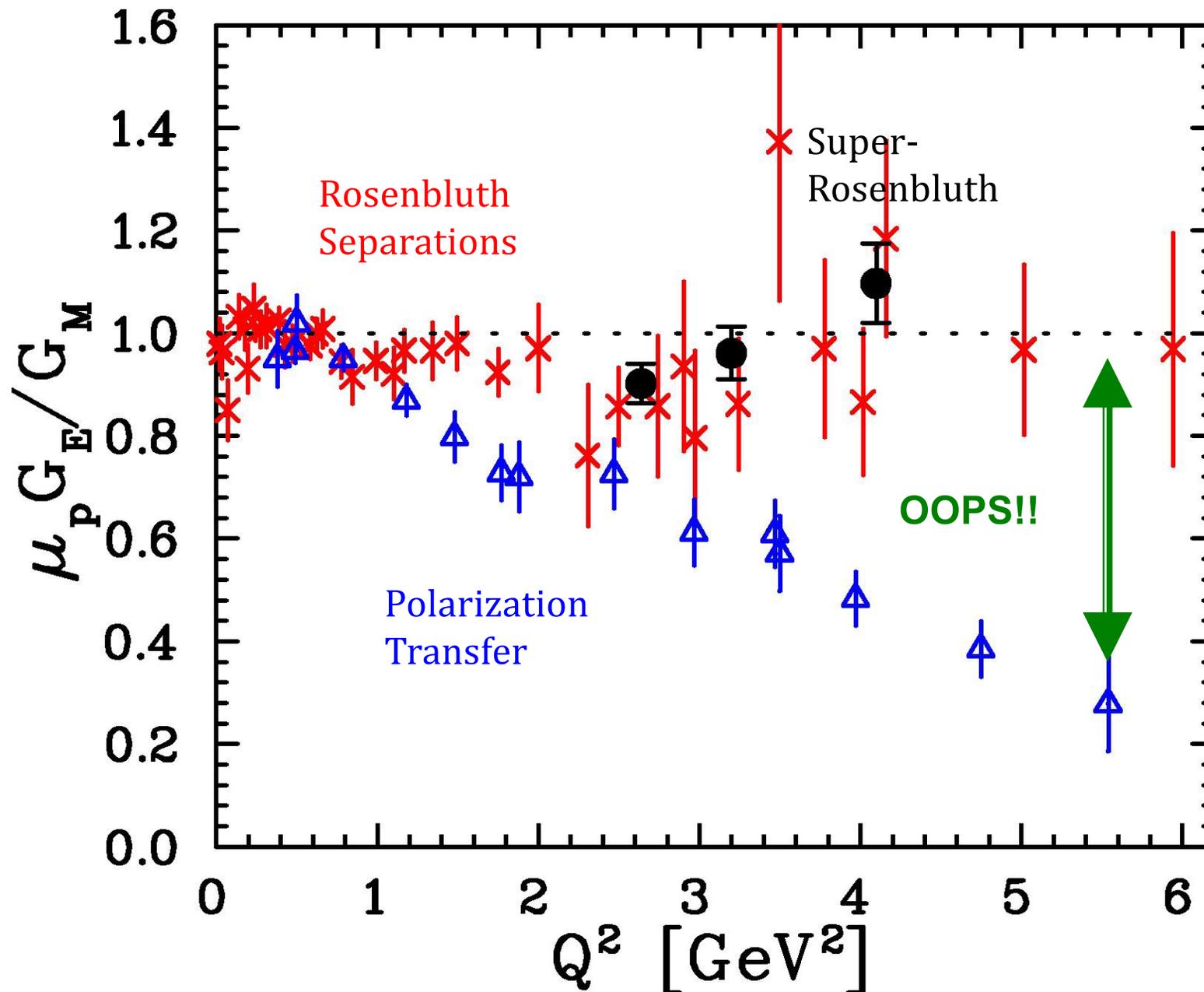
Focus on your message



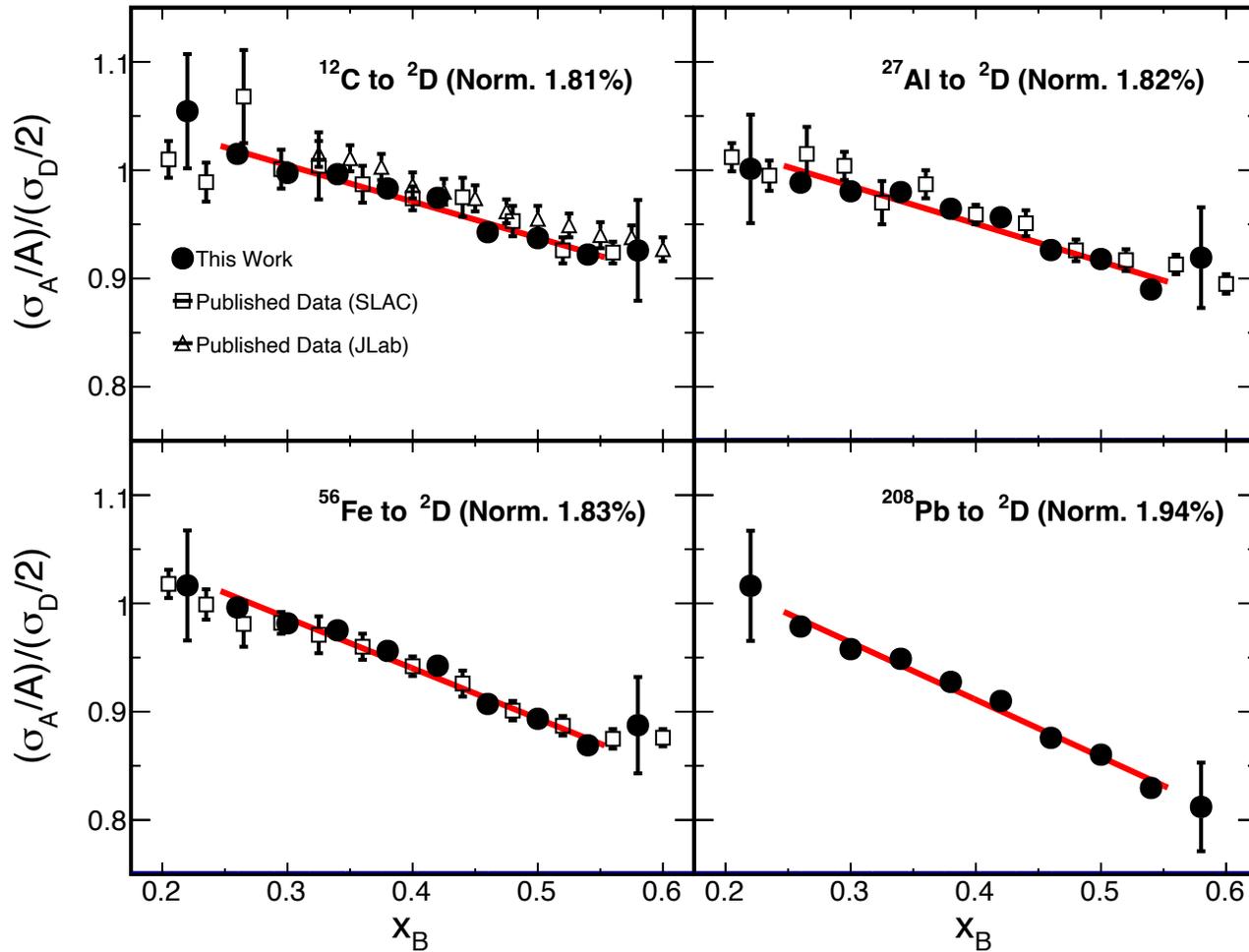
Focus on your message



Focus on your message

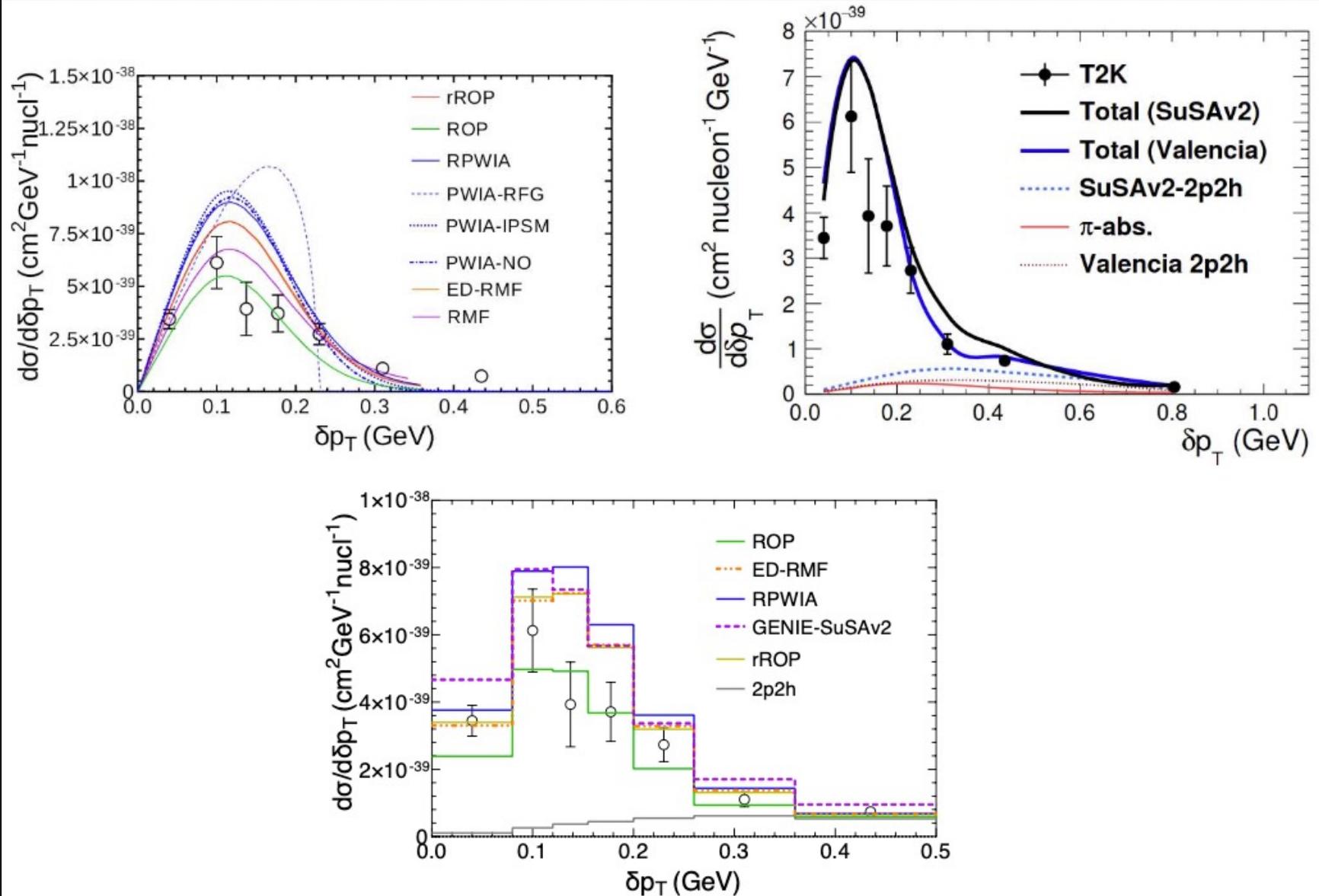


Emphasize thoughtfully

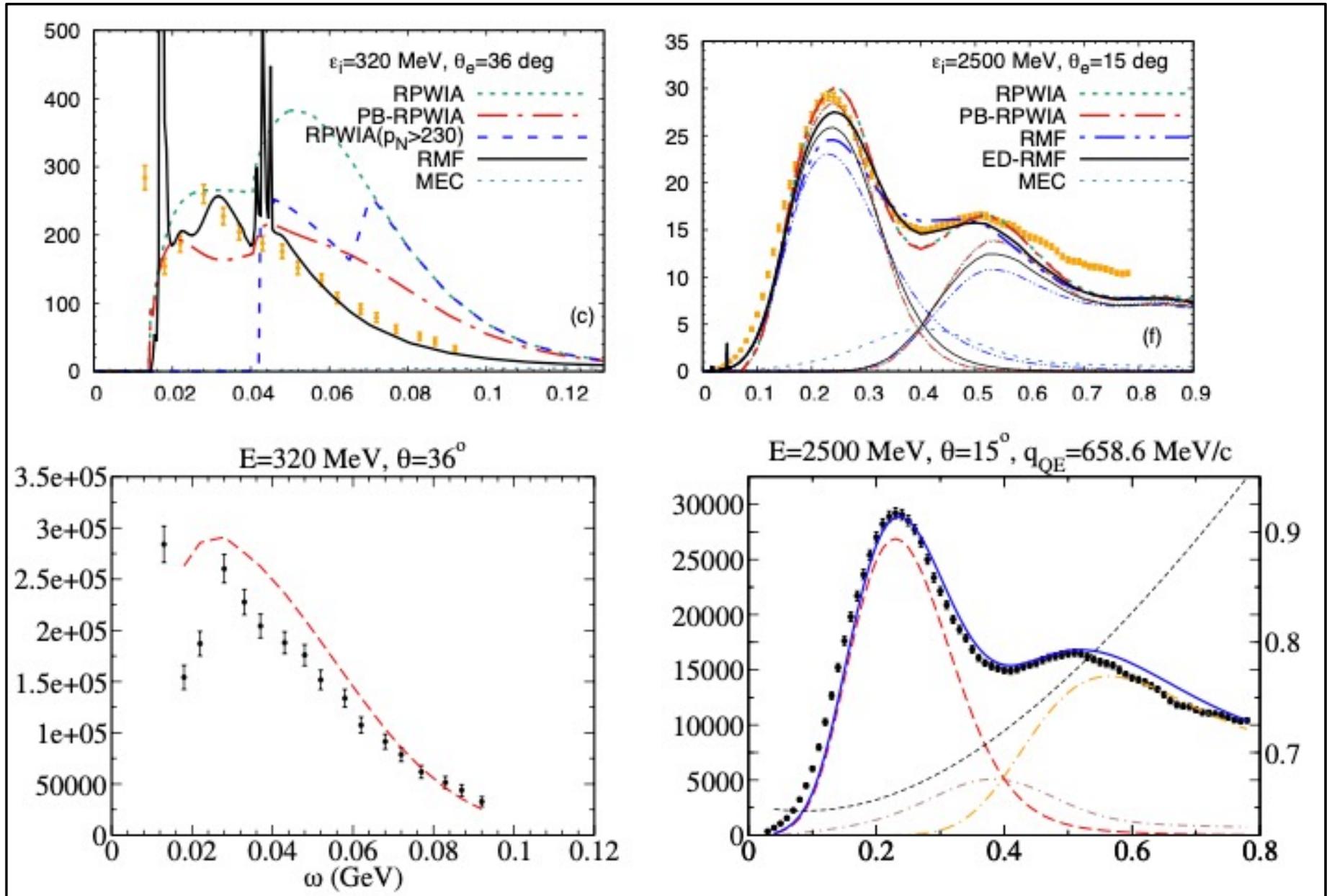


Plot data consistently

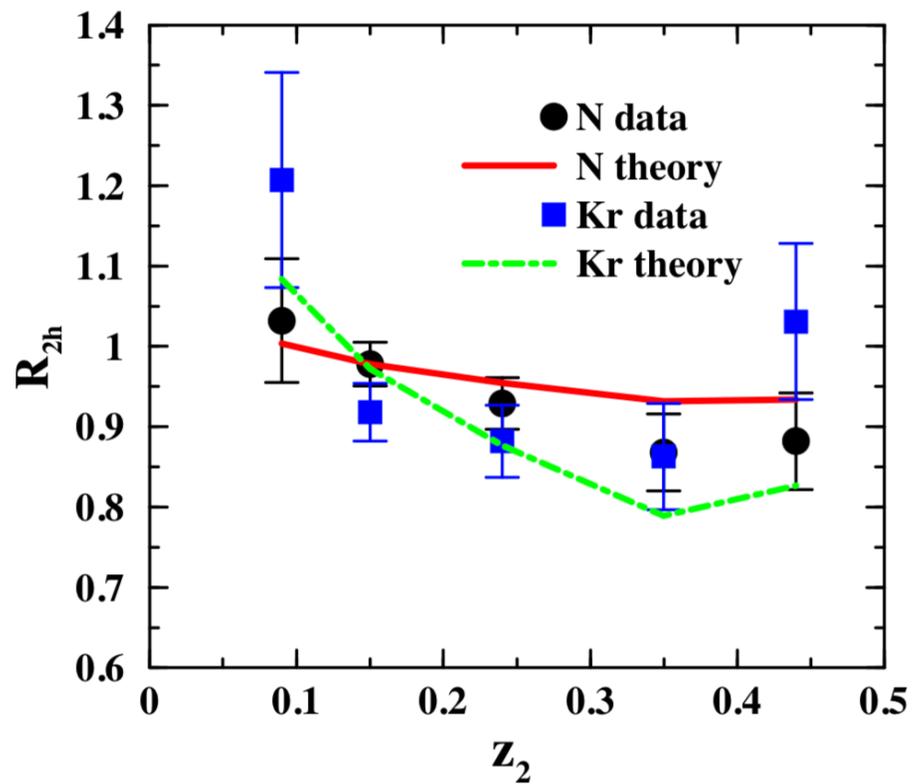
Analysis of FSI effects at T2K $CC0\pi$ and $CC0\pi Np$ data (J.F. Franco-Patino et al (in preparation))



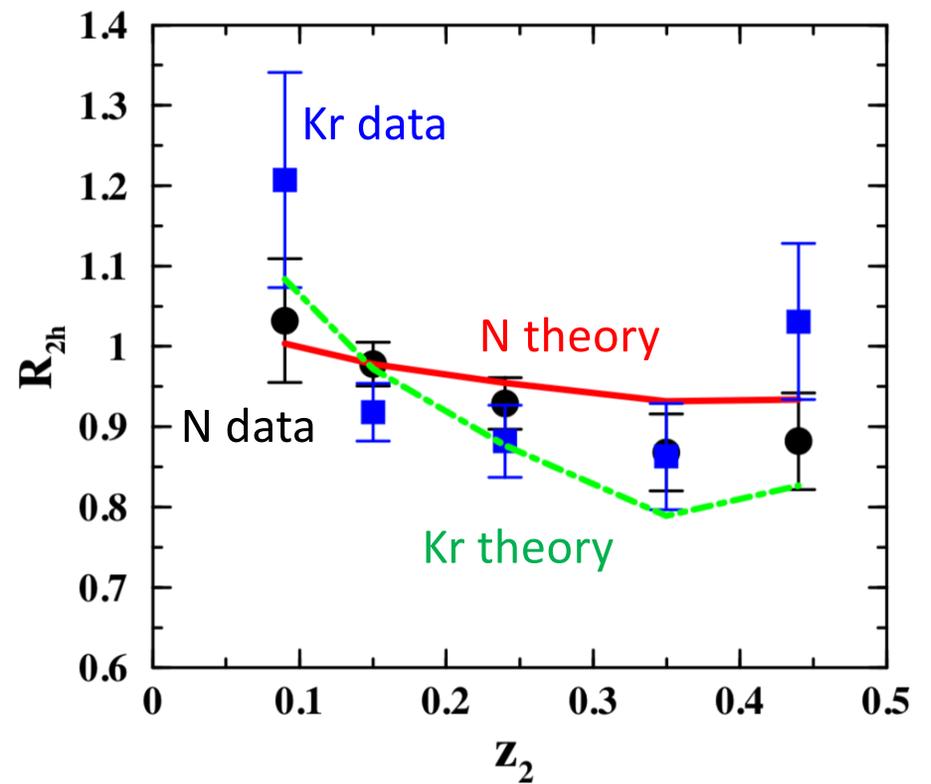
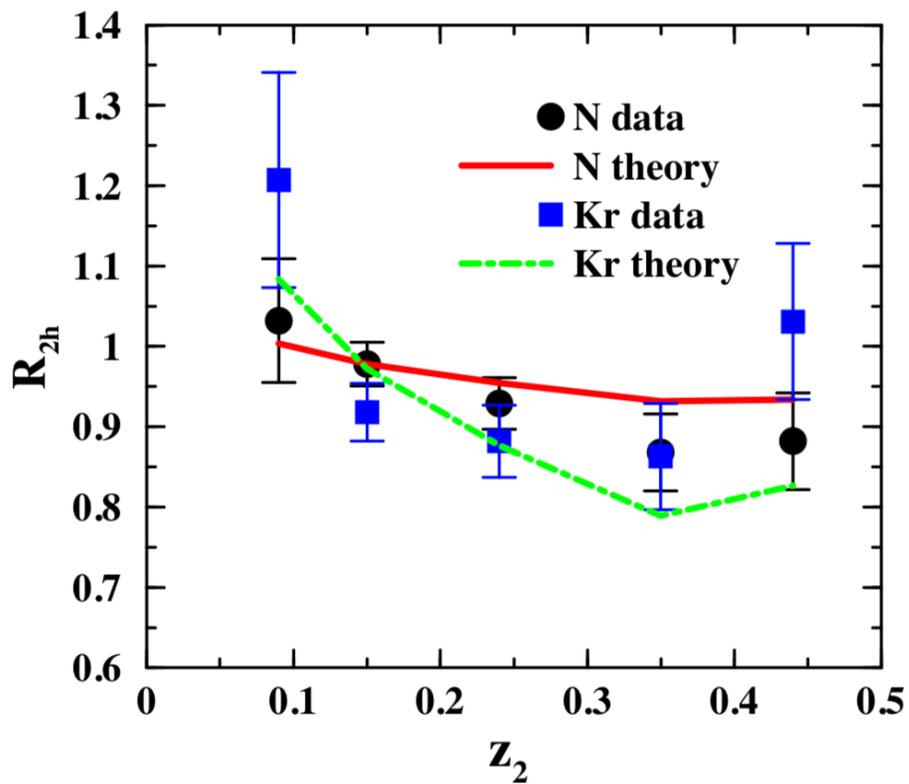
Plot data consistently



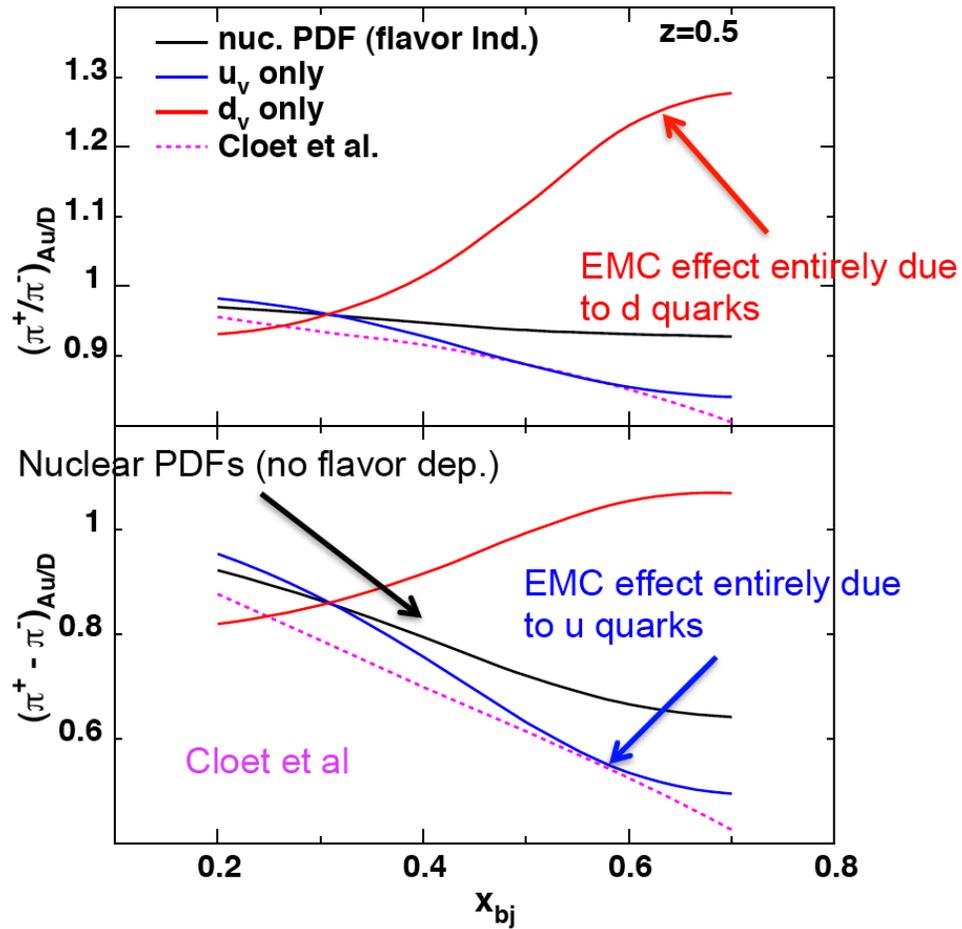
Labels not legends



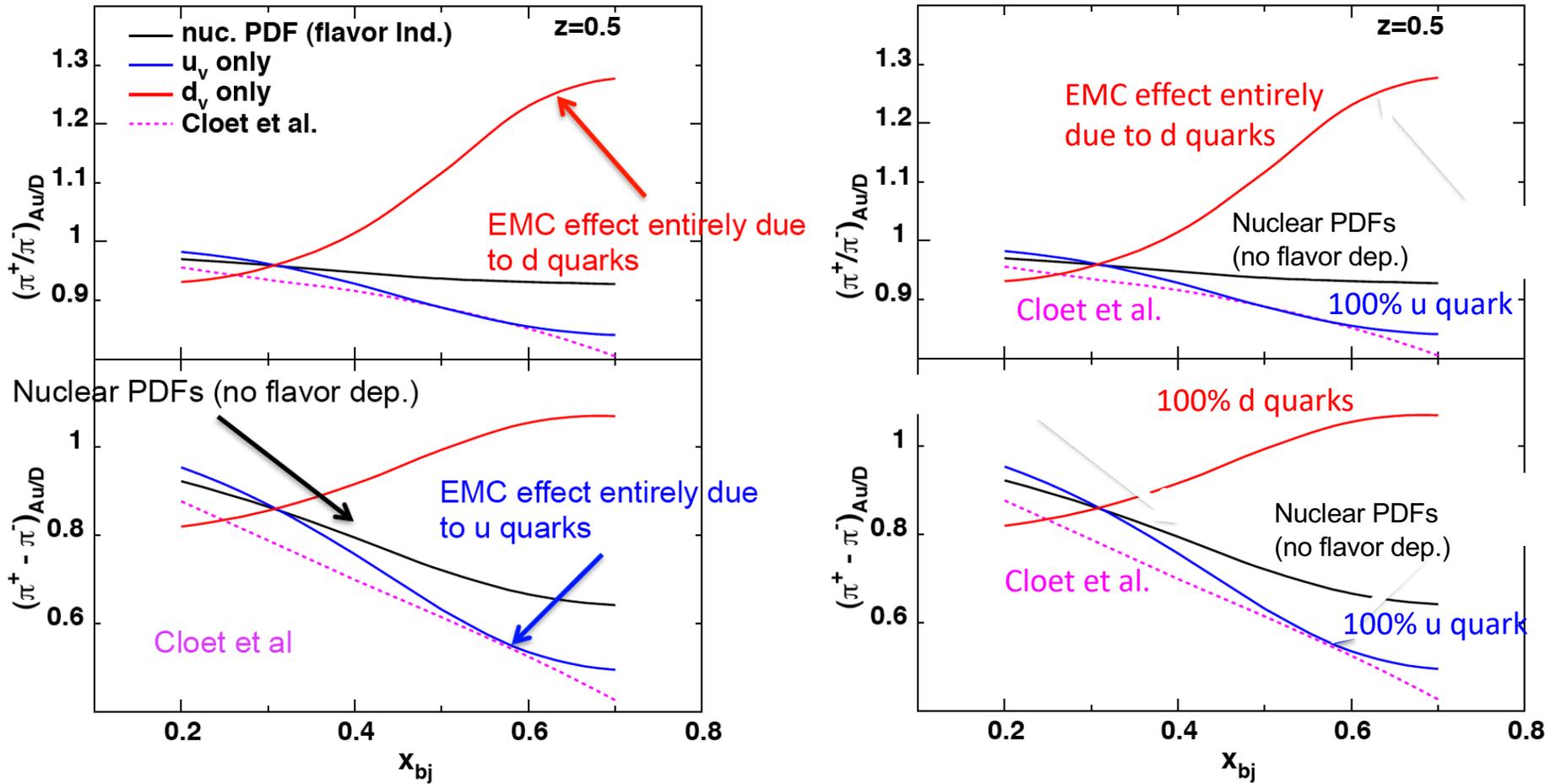
Labels not legends



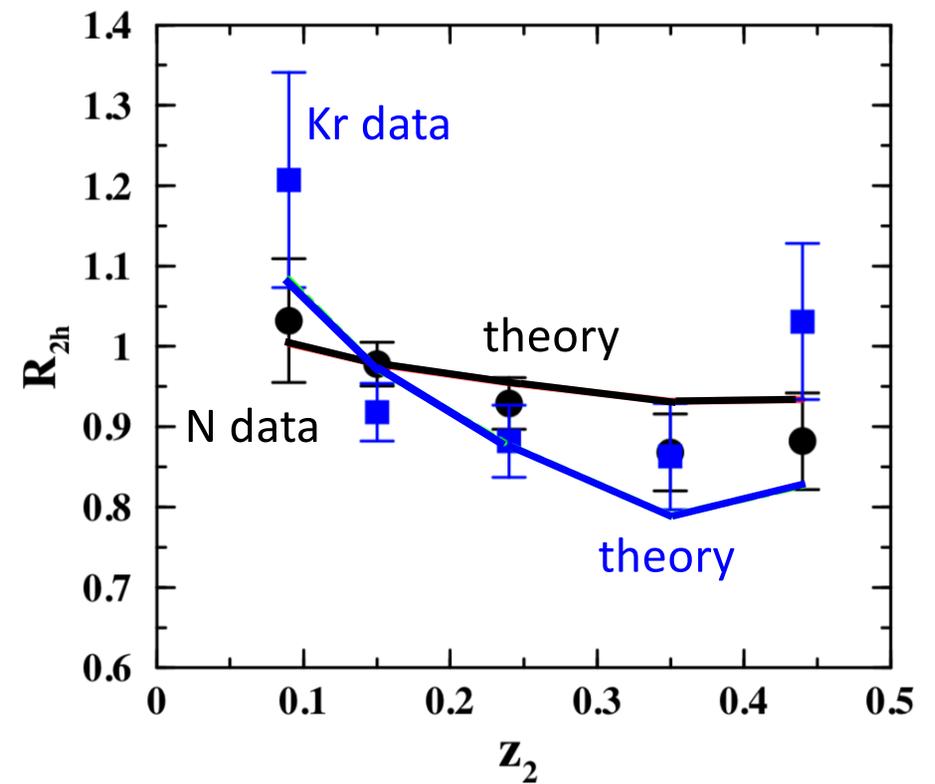
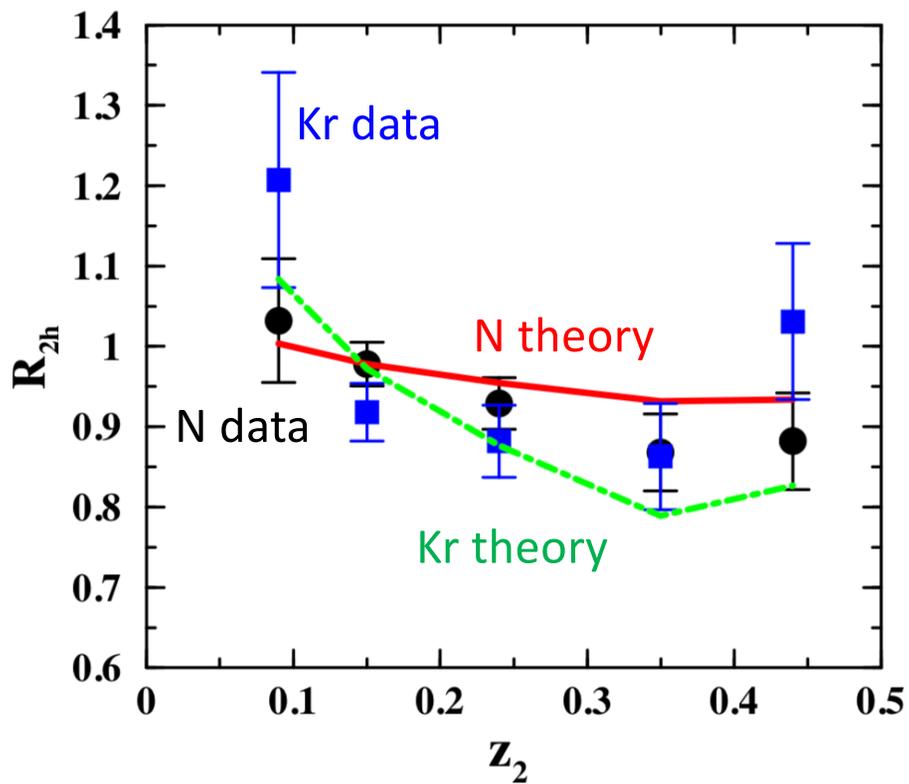
Avoid Arrows



Avoid Arrows

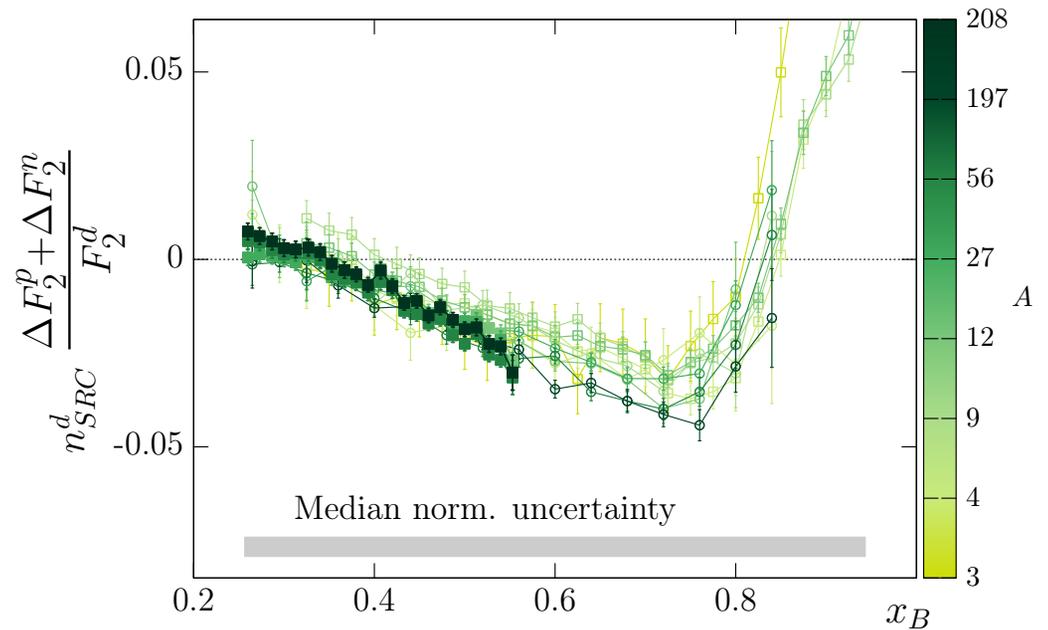
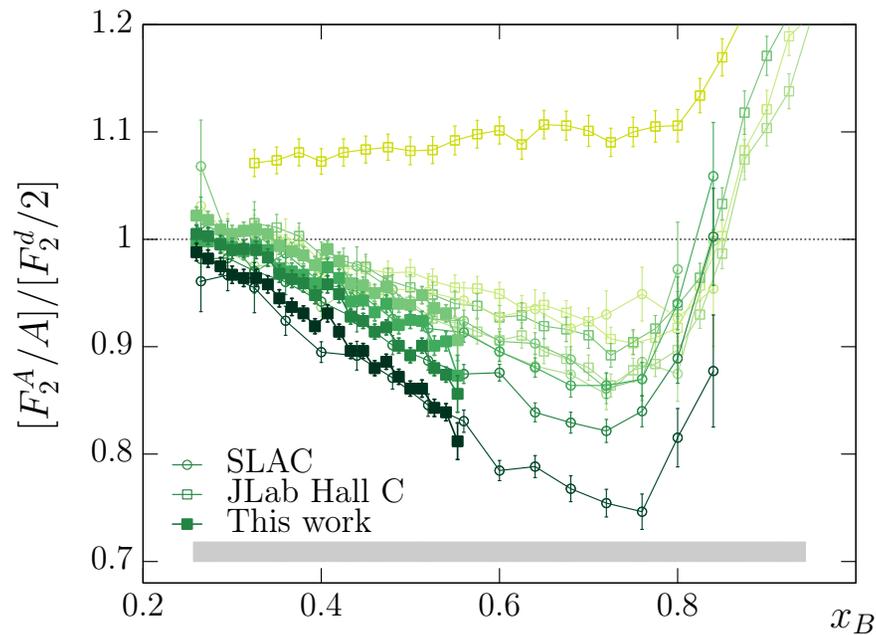


Colors matter



categorical color scale

Colors matter

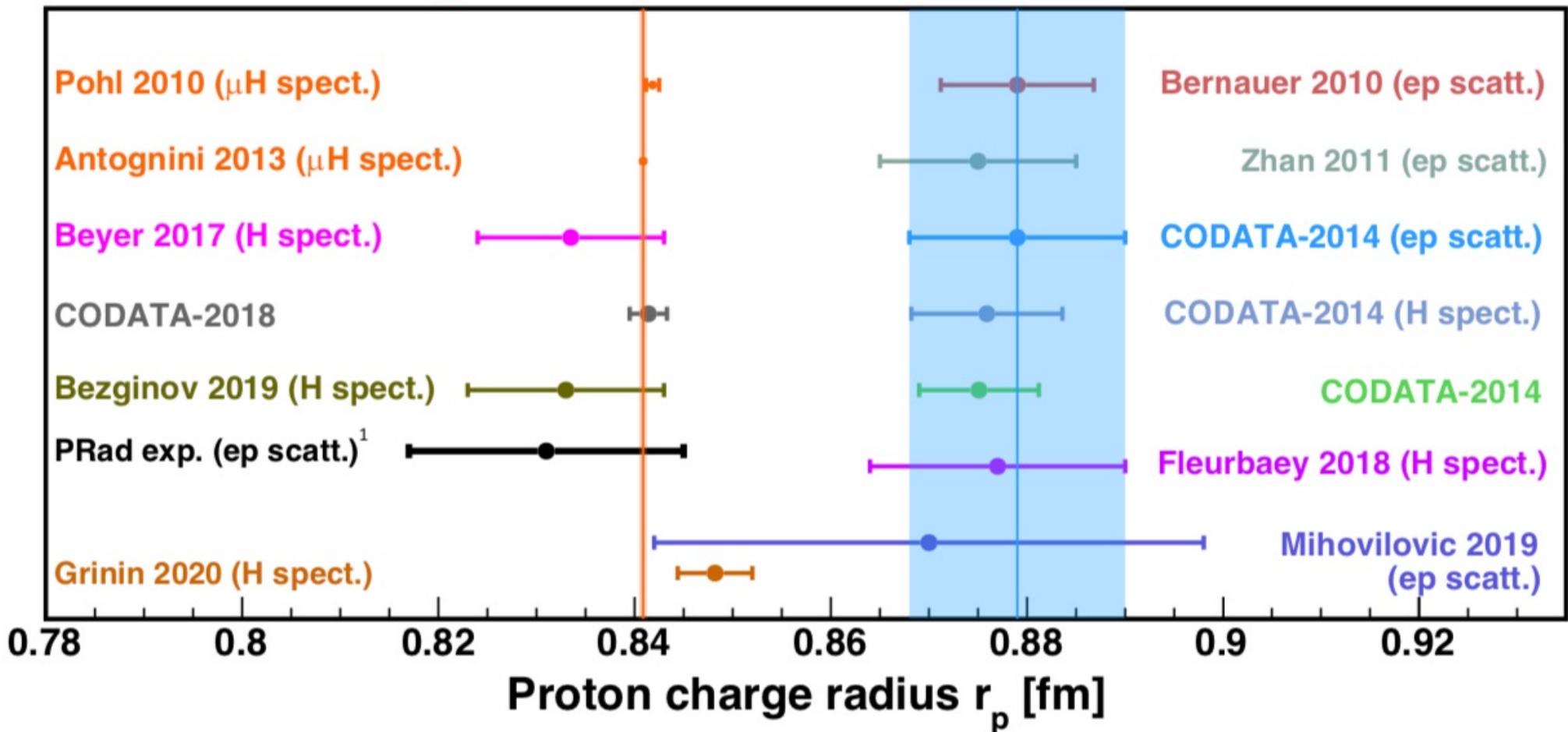


Sequential color scale

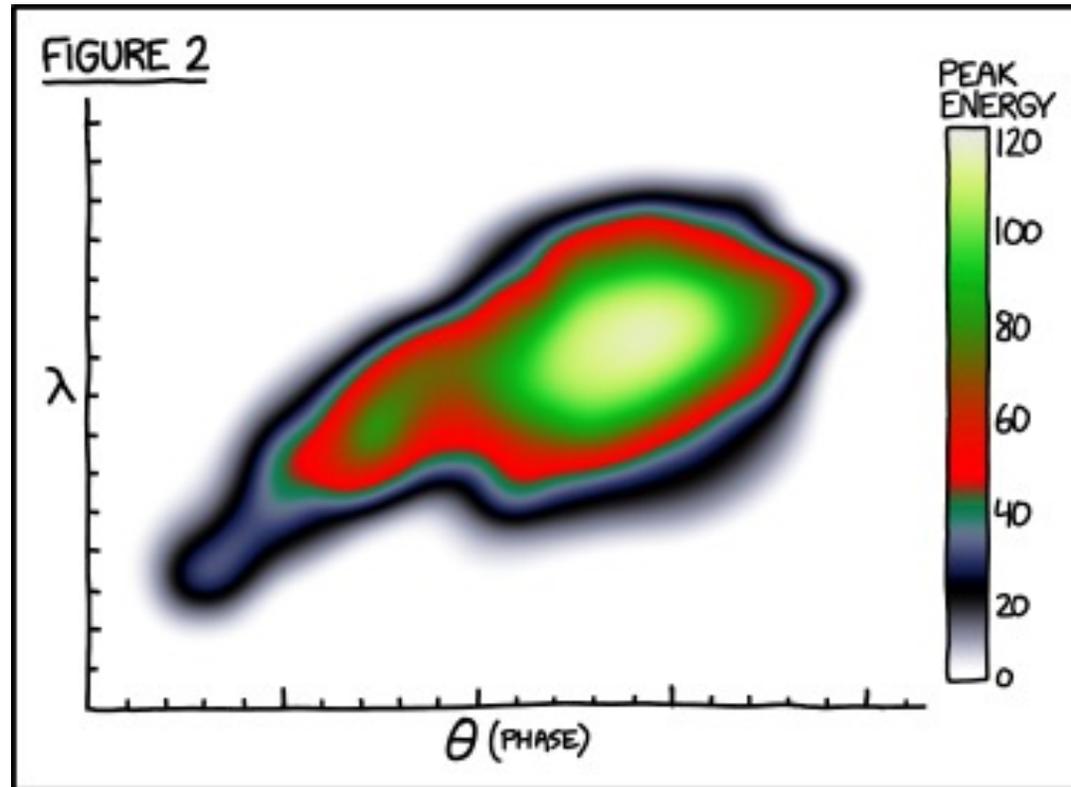
See <https://blog.datawrapper.de/which-color-scale-to-use-in-data-vis/>
and <https://blog.datawrapper.de/colorguide/>

Colors matter

PRad result: $r_p = 0.831 \pm 0.007$ (stat.) ± 0.012 (syst.) fm



Choose colors wisely

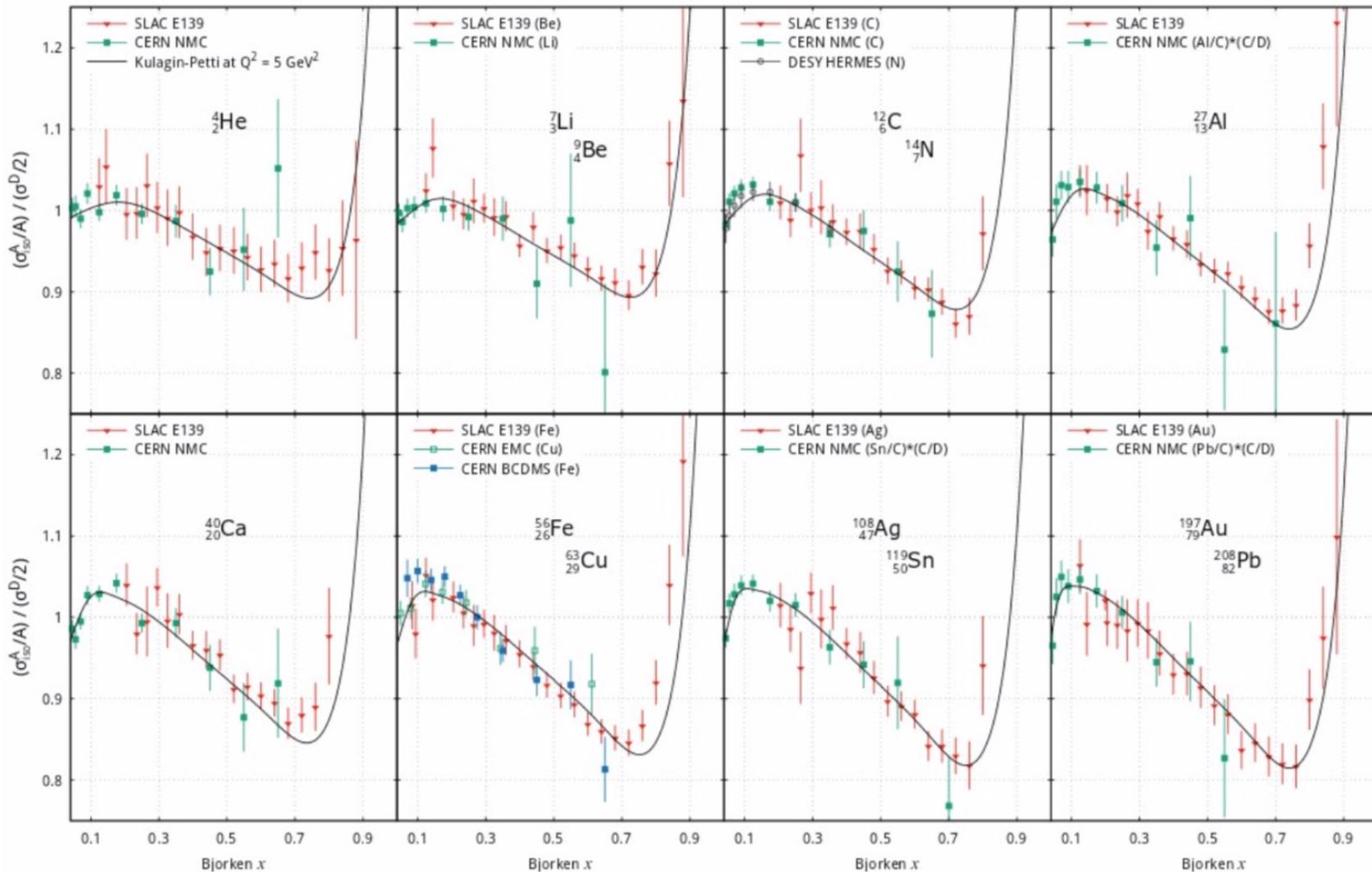


EVERY YEAR, DISGRUNTLED SCIENTISTS COMPETE FOR THE RAINBOW AWARD FOR WORST COLOR SCALE.

<https://xkcd.com/2537/>

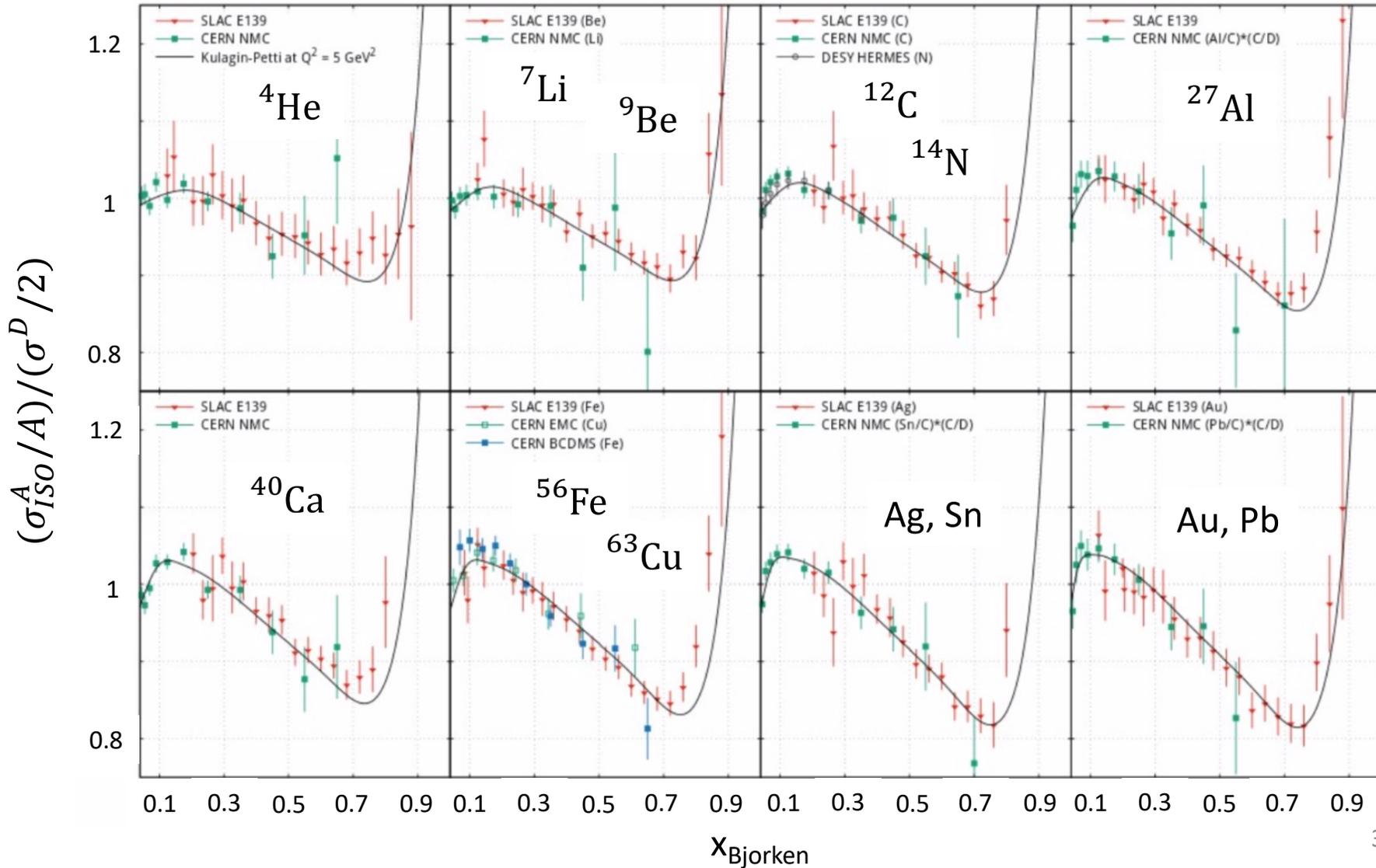
Makes axes legible

Compilation of EMC Effect Data by S. Kulagin and R. Petti SLAC E139-CERN



Makes axes legible

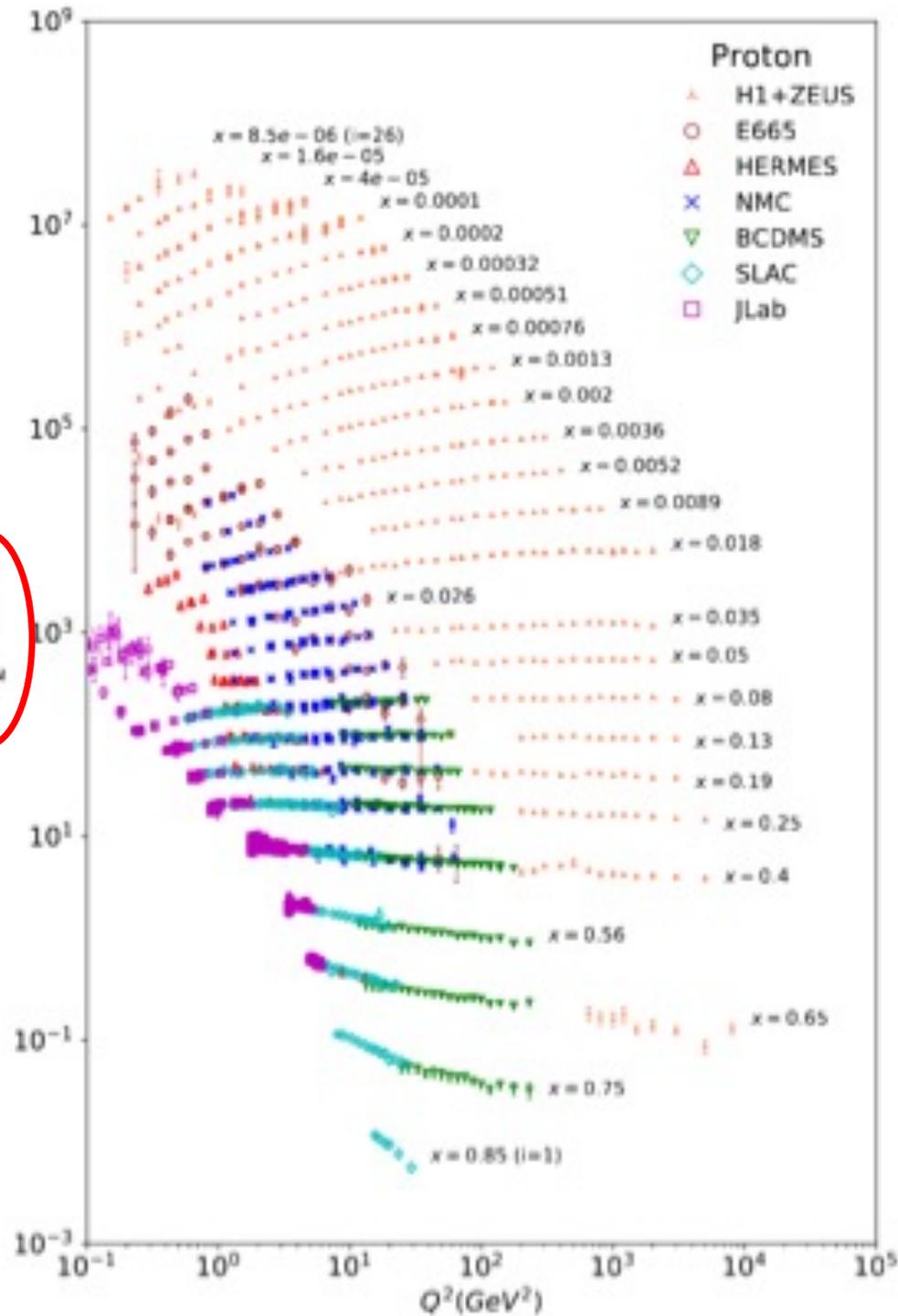
Compilation of EMC Effect Data by S. Kulagin and R. Petti
SLAC E139-CERN



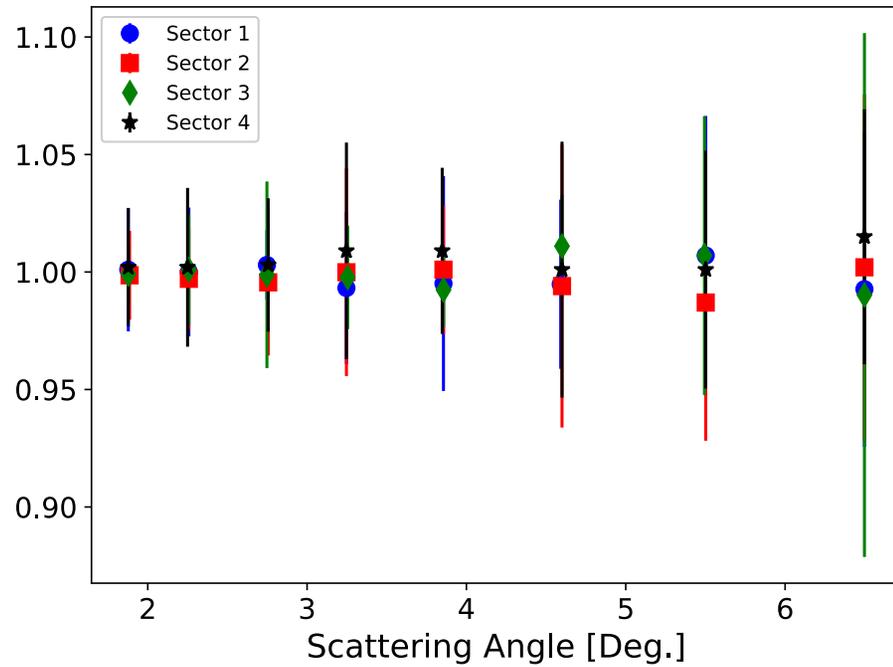
Offset
data
points
for
clarity
(vertical)

$$F_2^p \times 2^i$$

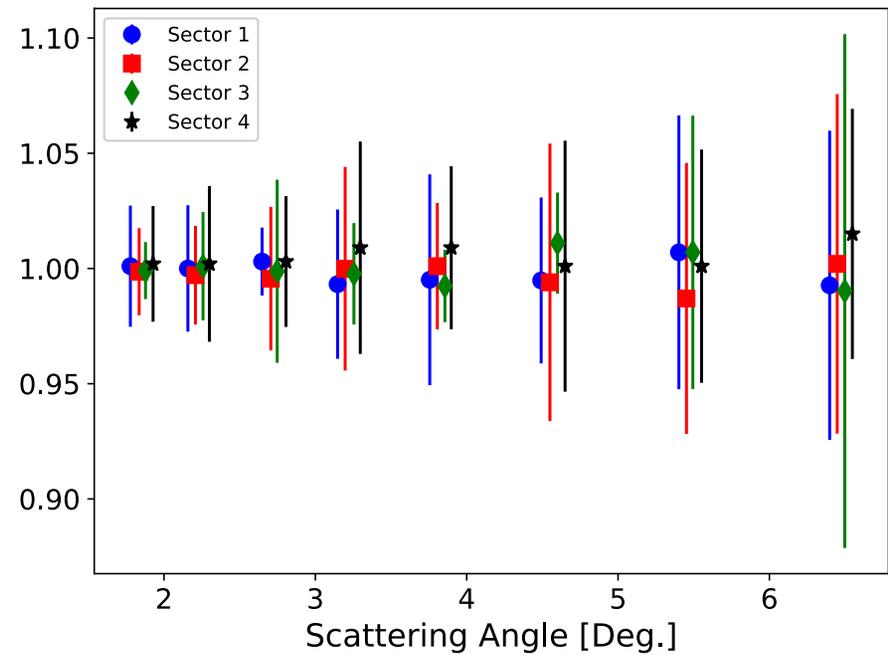
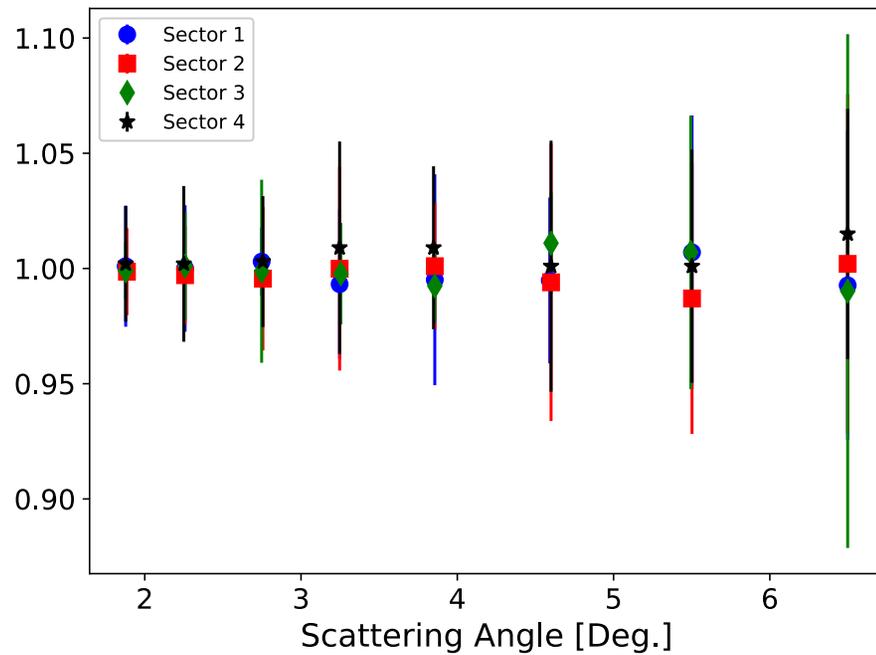
Each curve offset by
an extra factor of 2



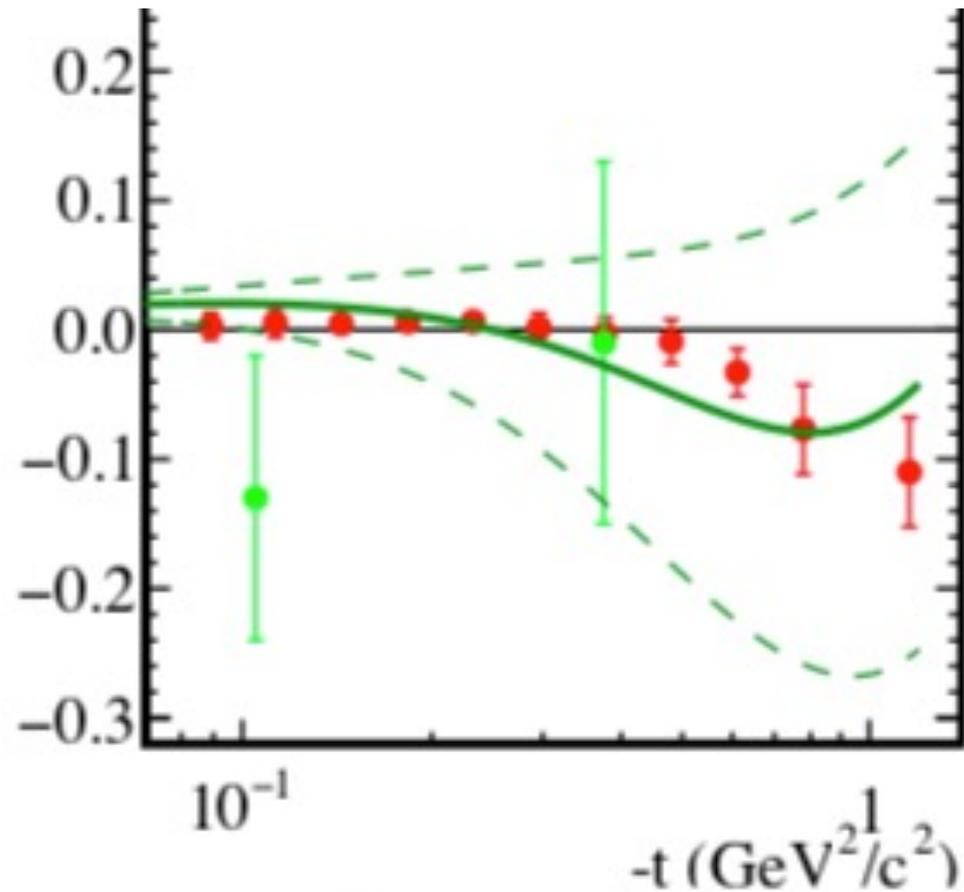
Offset data points for clarity (horizontal)



Offset data points for clarity (horizontal)



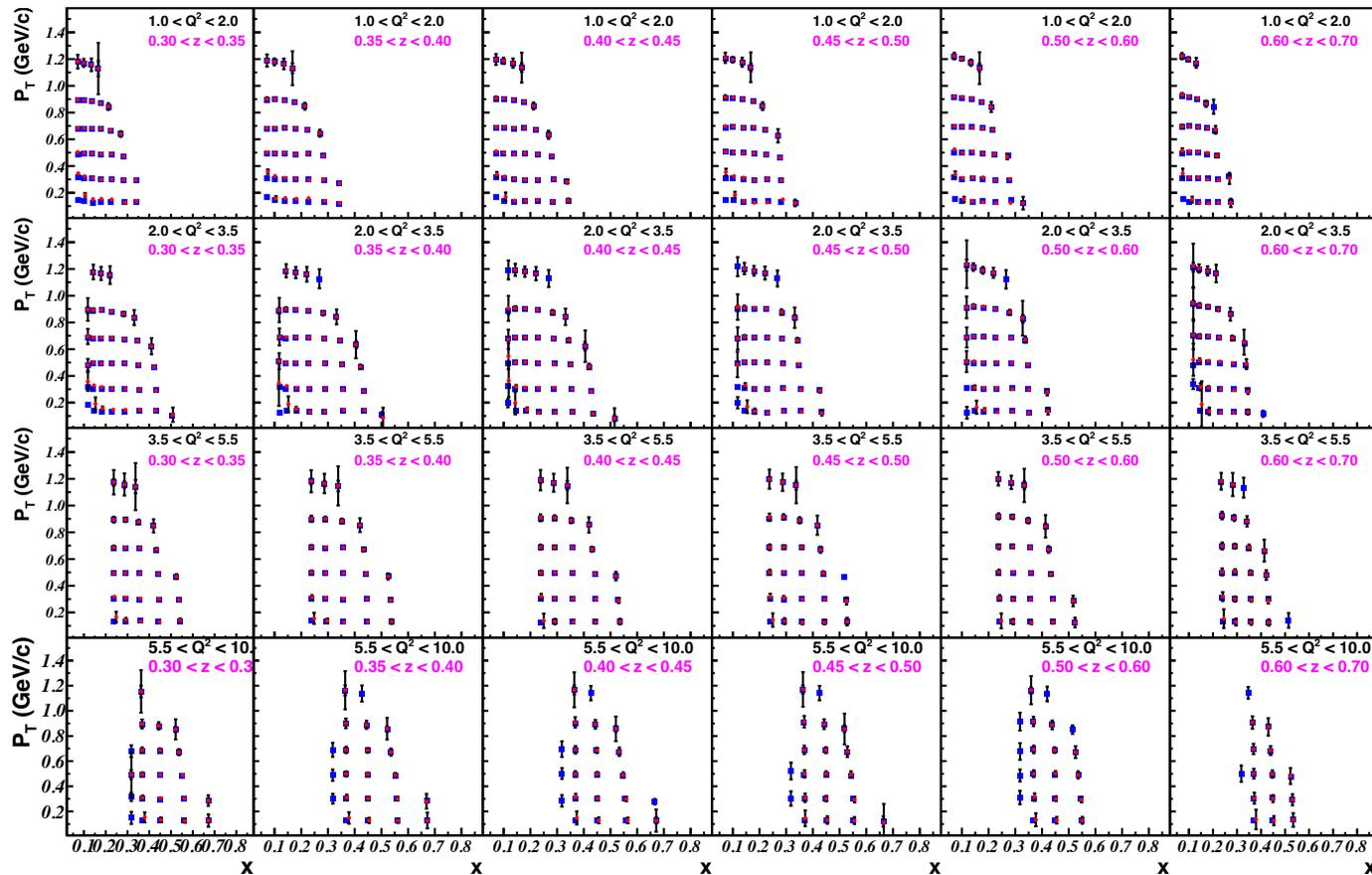
Be kind to the color blind
(and to black and white printers)



10% of males are red-green color blind

What are you showing?

Data PLUS context/interpretation.



All data. No interpretation. Who cares?

Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813.

Dressée par M. Minard, Inspecteur Général des Ponts et Chaussées en retraite. Paris, le 20 Novembre 1869.

Les nombres d'hommes présents sont représentés par les largeurs des zones colorées à raison d'un millimètre pour dix mille hommes; ils sont de plus écrits en traits de des zones. Le rouge désigne les hommes qui ont été en Russie, le noir ceux qui en sont sortis. Les renseignements qui ont servi à dresser la carte ont été puisés dans les ouvrages de M. M. Chiers, de Féguir, de Fezensac, de Chambray et le journal inédit de Jacob, pharmacien de l'Armée depuis le 28 Octobre. Pour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Prince Jérôme et du Maréchal Davoust qui avaient été détachés sur Minsk et Mohilow et ont rejoint vers Orscha et Witebsk, avaient toujours marché avec l'armée.

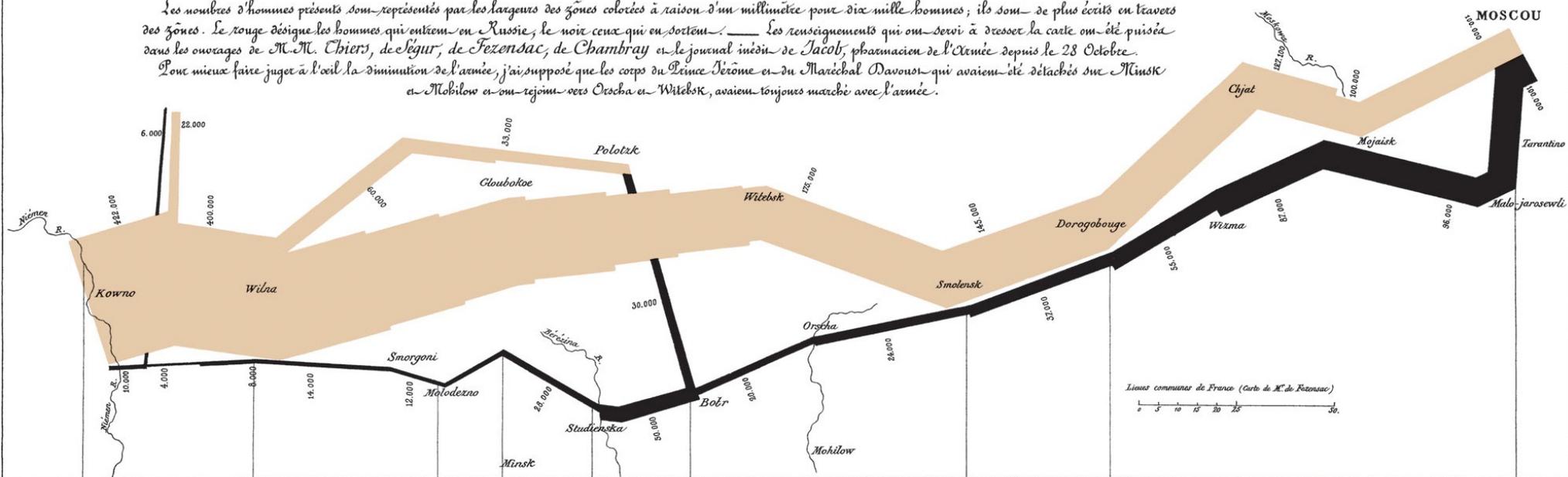
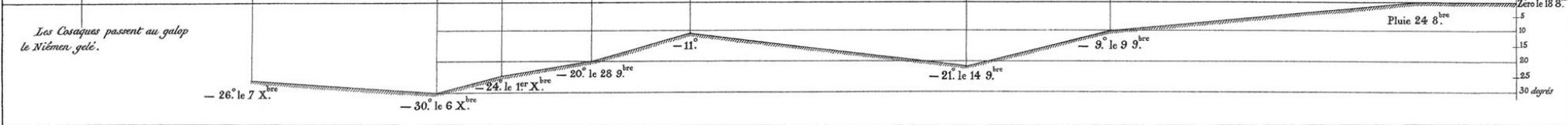


TABLEAU GRAPHIQUE de la température en degrés du thermomètre de Réaumur au dessous de zéro.



Autog. par Regnier, R. Pas. 5^{me} Marie St G^{de} à Paris.

Imp. Lit. Regnier et Douard.

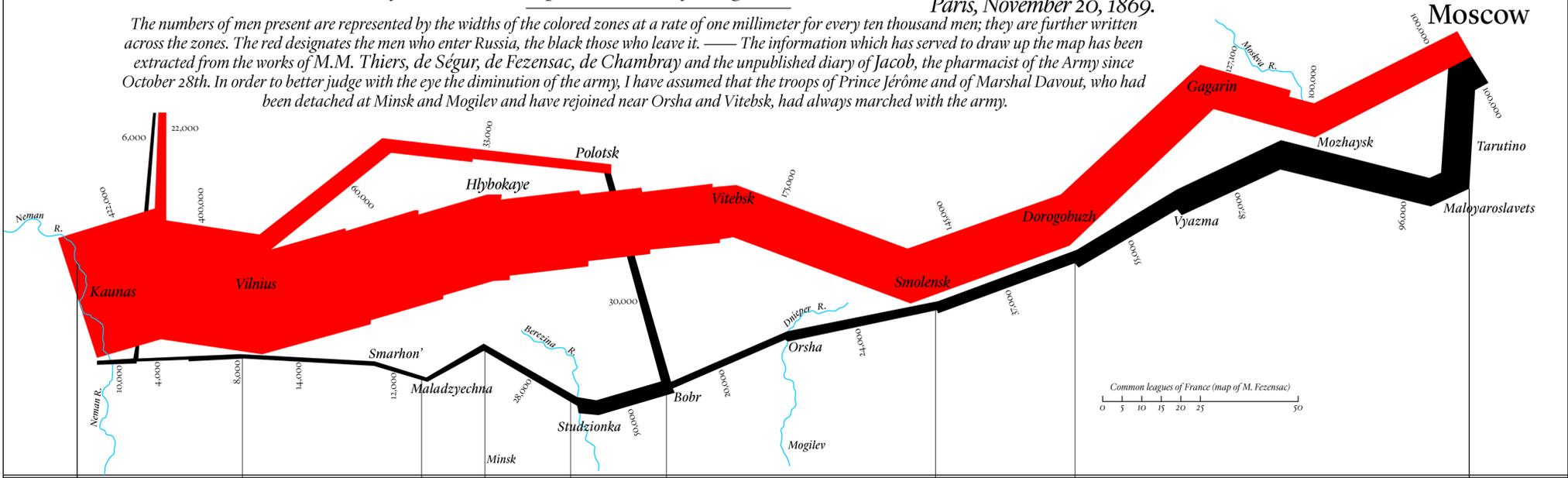
Charles Joseph Minard, Losses from the Russian Campaign, 1869

Figurative Map of the successive losses in men of the French Army in the Russian campaign 1812 ~ 1813

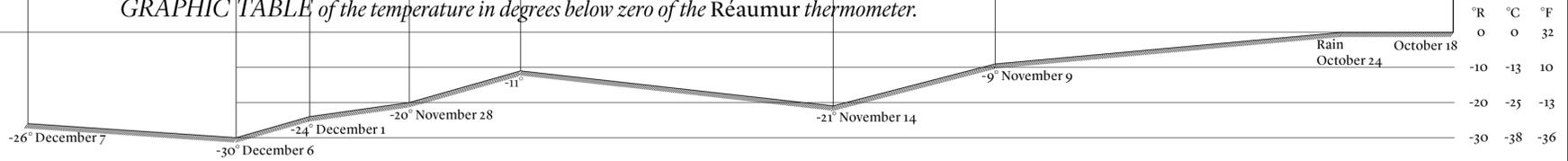
Drawn by M. Minard, Inspector General of Bridges and Roads (retired).

Paris, November 20, 1869.

The numbers of men present are represented by the widths of the colored zones at a rate of one millimeter for every ten thousand men; they are further written across the zones. The red designates the men who enter Russia, the black those who leave it. — The information which has served to draw up the map has been extracted from the works of M.M. Thiers, de Ségur, de Fezensac, de Chambray and the unpublished diary of Jacob, the pharmacist of the Army since October 28th. In order to better judge with the eye the diminution of the army, I have assumed that the troops of Prince Jérôme and of Marshal Davout, who had been detached at Minsk and Mogilev and have rejoined near Orsha and Vitebsk, had always marched with the army.



GRAPHIC TABLE of the temperature in degrees below zero of the Réaumur thermometer.



The Cossacks pass the frozen Neman at a gallop.

Charles Joseph Minard, Losses from the Russian Campaign, 1869

Translated and recolored

<https://edspace.american.edu/visualwar/minard/>

Summary

Know your audience and your goal

Minimize the time needed to understand your plots

- Eliminate chart junk
- Maximize data/ink ratio
- Avoid distractions
- Focus the plot on your message

- Emphasize with care
- Labels not legends
- Avoid arrows
- Colors matter
- Make axes legible
- Offset data points for clarity
- Be kind to the color blind

What's the money plot?

Edward Tufte, "The Visual Display of Quantitative Information"