^{56}Fe Evaluation for the CIELO Project

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mini-CSEWG 2016, April 11-12

^{56}Fe CIELO collaboration

BNL, CNDC, IAEA, IRM, JSI, LANL, ORNL, RPI

- Exp. data analysis: CNDC
- Resonance range: initially ORNL, recently BNL & IAEA
- Fast neutron range: EMPIRE (BNL, IAEA)
- File assembly: IAEA, BNL
- Testing: IAEA, RPI, BNL, LANL, JSI

- **Recent developments**
  - Update of 56Fe
    - Modifications of RR
    - Elastic angular distributions
    - New fast neutron evaluation using PE exciton model for all channels
    - Capture above 1.3 MeV lowered (following RPI data)
    - (n,2n) slightly changed, inelastic consistent with v.88
  - New evaluations for 54,57,58Fe
    - RR for 54,57 (LRF=7),
  - Covariances for 54,56,57Fe

Status of ^{56}Fe CIELO evaluation

- Rev.49
  - RR - ORNL rev.43 up to 2 MeV
  - Fast - EMPIRE calculations with HFB level dens. rev.48
  - X-sec fluctuations ignored
  - Elastic ang. distributions
    - RR: JENDL-4.0 (aver. fluct.)
    - rest: EMPIRE (no fluctuations)

- Rev.88 (CSEWG-2015)
  - RR - ORNL rev.43 up to **846** keV
  - **Total 846 keV - 4 MeV: JEFF-3.2 (smoothed Berthold data)**
  - **MT51,52 up to 4 MeV: Negret (Geel) data**
  - All the rest except elastic: EMPIRE calculations with **GC** level densities
  - X-sec fluctuations **included**
  - Elastic ang. distributions
    - RR: JENDL-4.0 (aver. fluct.)
    - rest: EMPIRE (no fluctuations)

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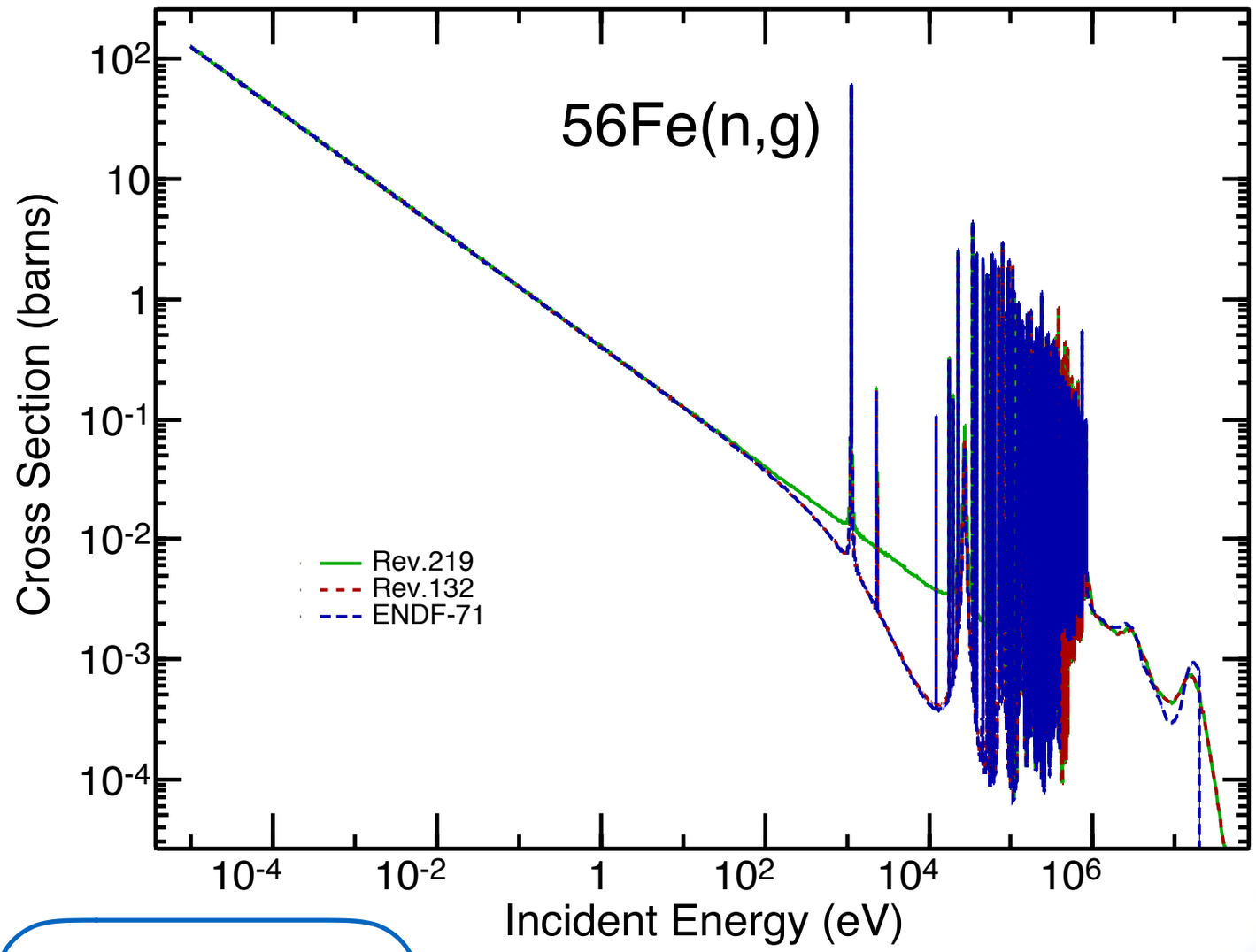
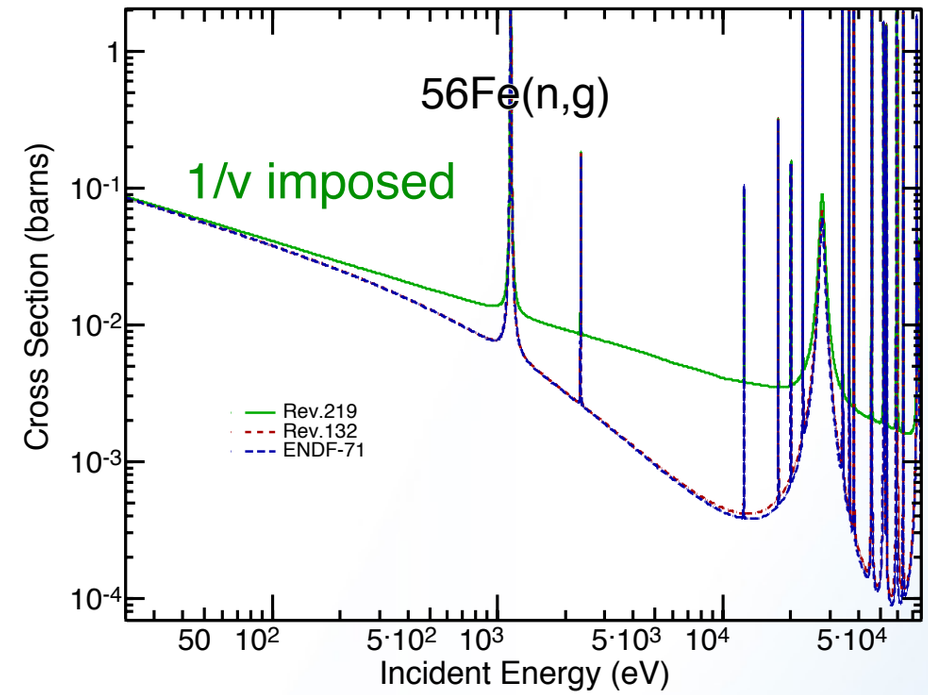
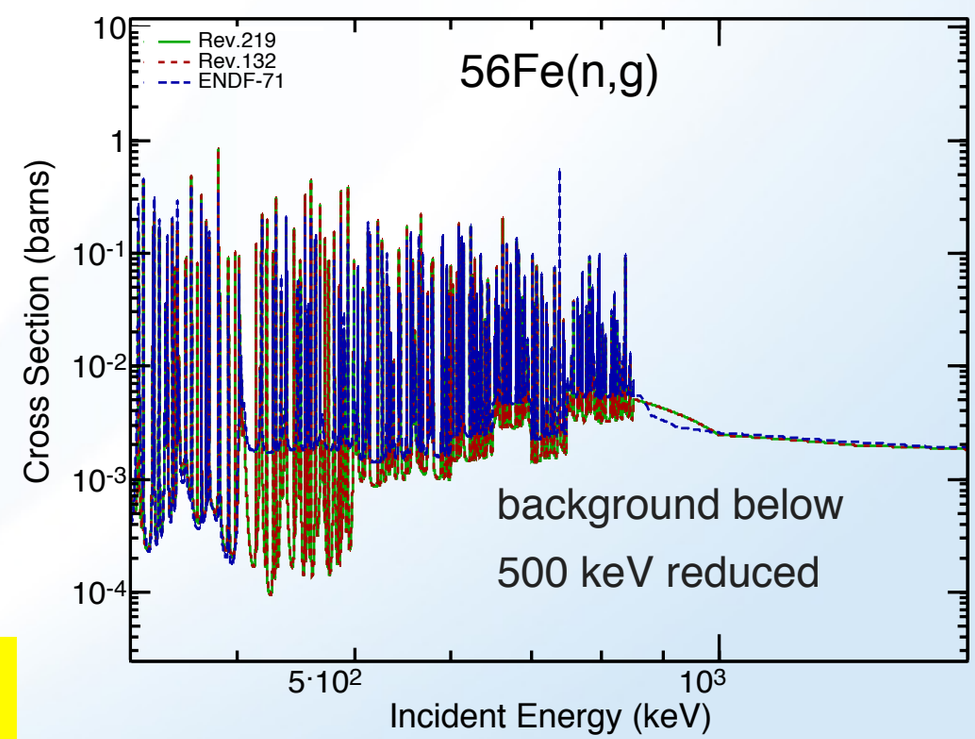
- Rev.219 (mini-CSEWG-16) 'fe56ib15k'
  - RR - JENDL-4.0 up to 850 keV
    - resonance energy at 766.7 keV was corrected
    - background added to capture around 24.5 keV
    - background below 400 keV reduced by 40% (capture, elastic)
  - Total 850 keV - 6 MeV: JEFF-3.2 (smoothed Berthold data)
  - MT51,52 up to 3.5 MeV: consistent combination of Dupont and Negret data
  - All the rest except elastic: EMPIRE calculations with GC level densities
  - X-sec fluctuations included
  - Elastic ang. distributions
    - RR: JENDL-4.0 (aver. fluct.)
    - above RR up to 4 MeV fluct. taken from JEFF-3.2 (JEF-2.2) following Kinney data
    - rest: EMPIRE (no fluctuations)

Changes to the RR region







Thermal capture x-sec

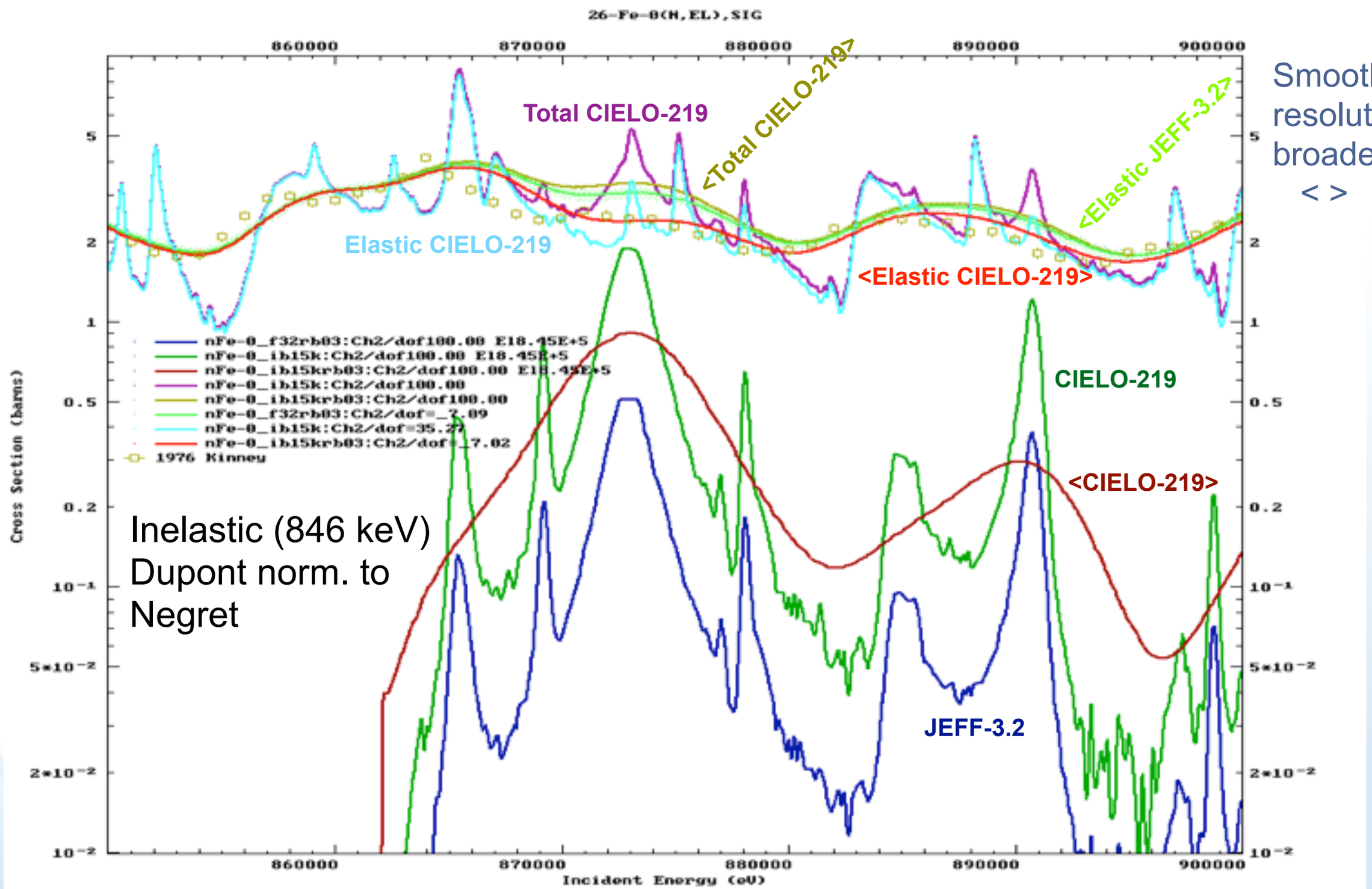
Atlas:	2.59(14)
EGAF:	2.71(4)
CIELO r.291:	2.6051
ENDF/B-VII.1:	2.58936
ENDF/B-VII.0:	2.58933

Changes driven by integral testing…

We don't like background…

RR in 56Fe still calls for attention

nat-Fe: Total, Elastic, Inelastic 850-900 keV



Smooth lines resolution-broadened
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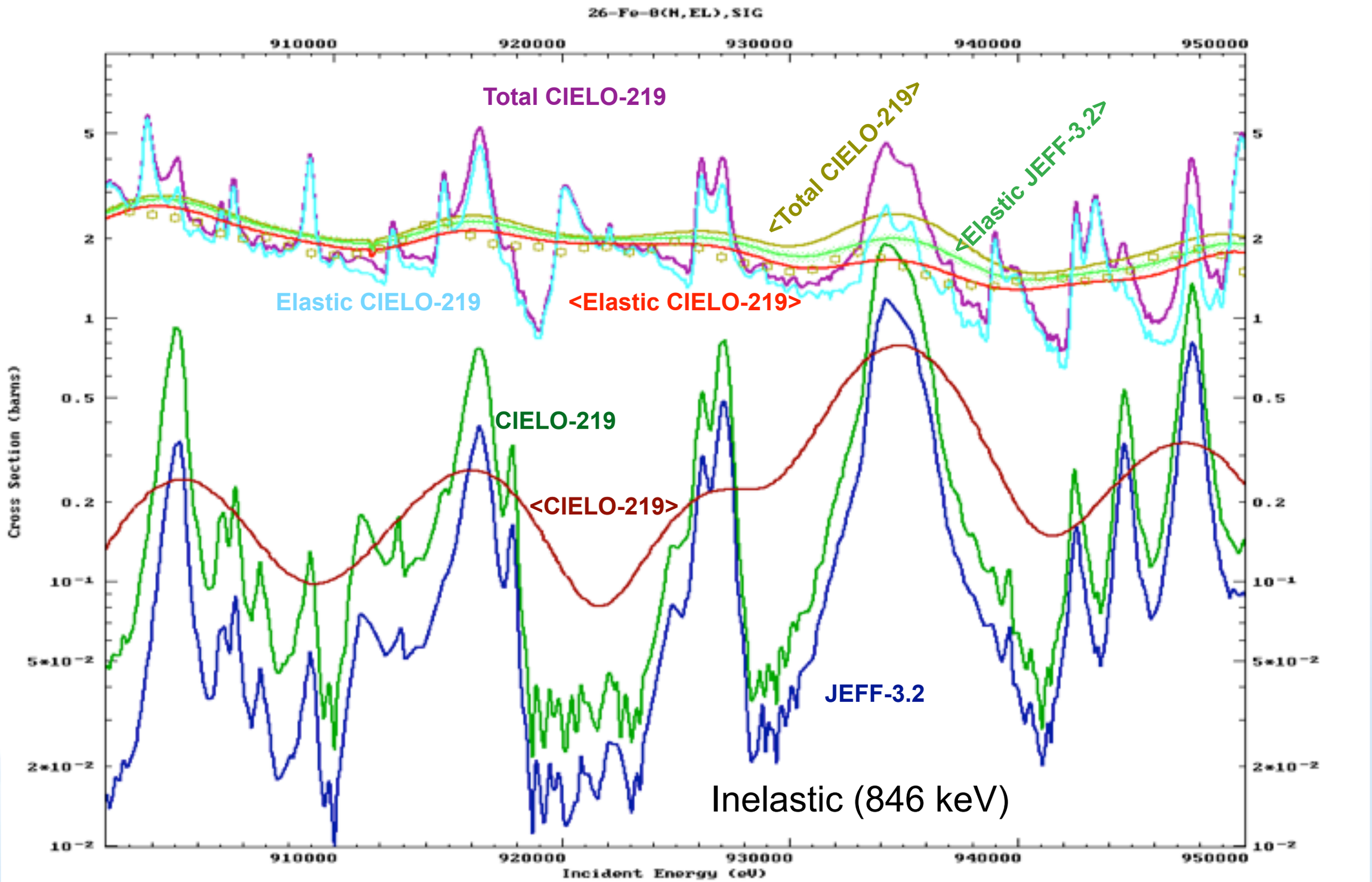
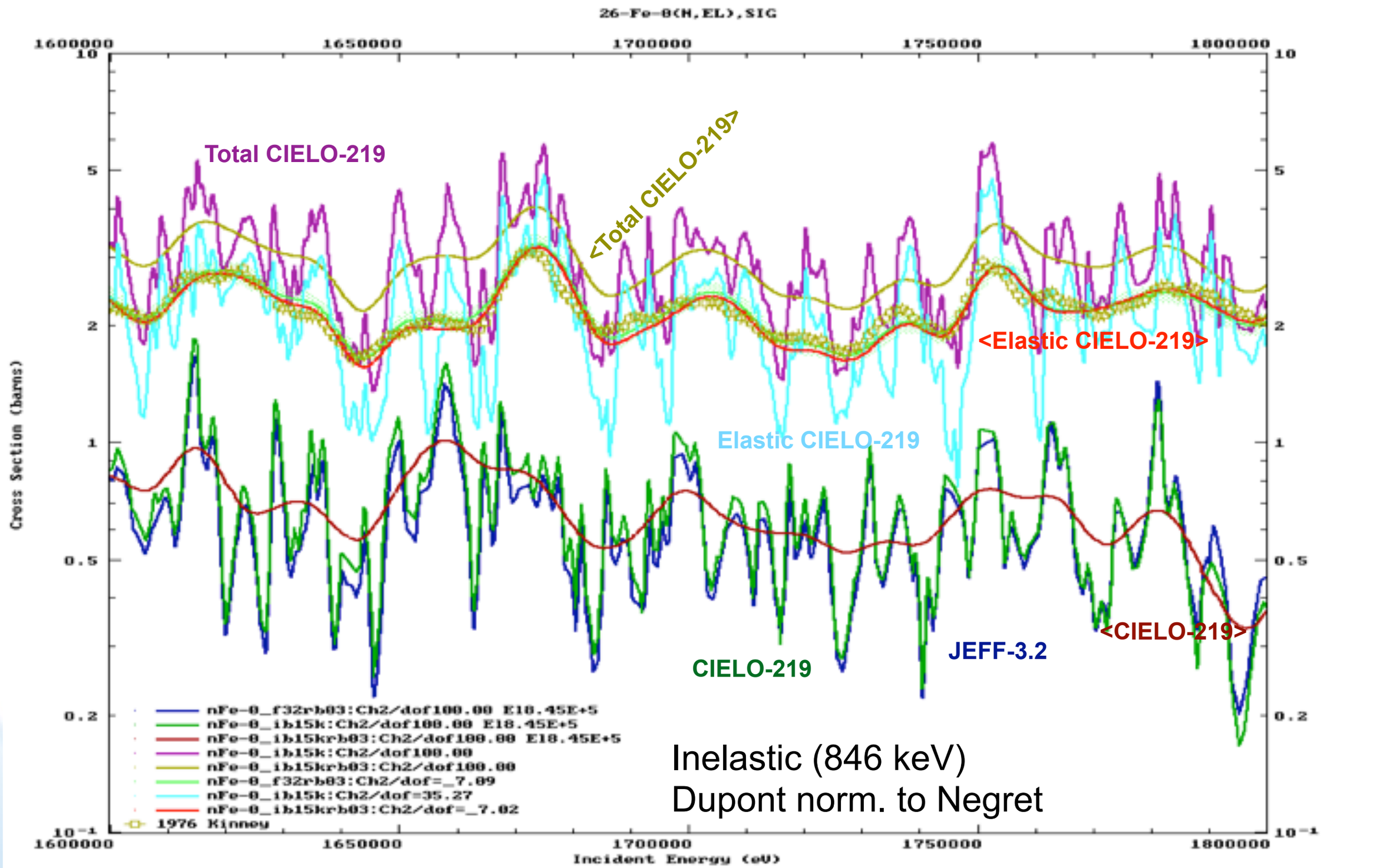
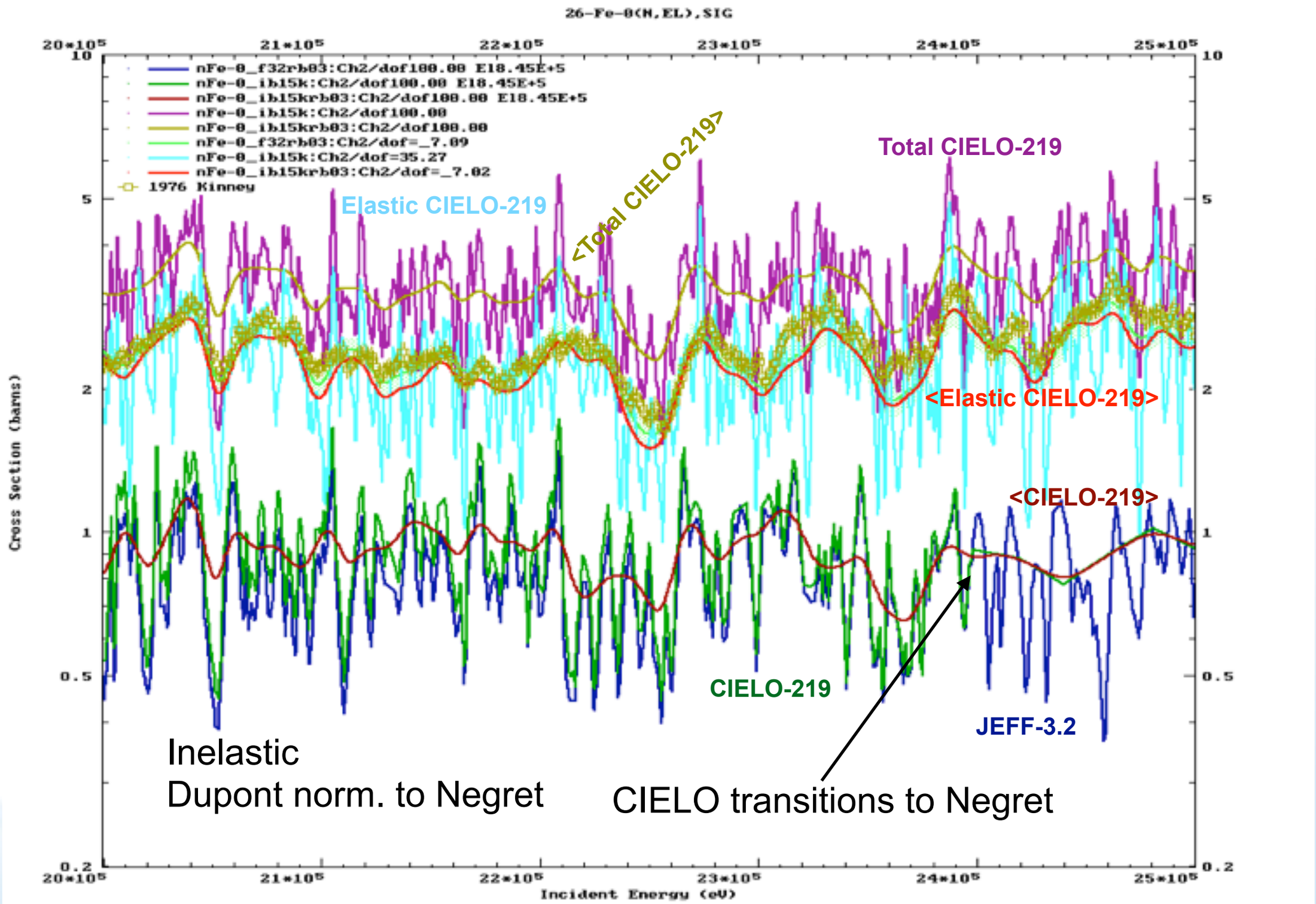
nat-Fe: Total, Elastic, Inelastic 900-950 keV



nat-Fe: Total, Elastic, Inelastic 1.60-1.80 MeV



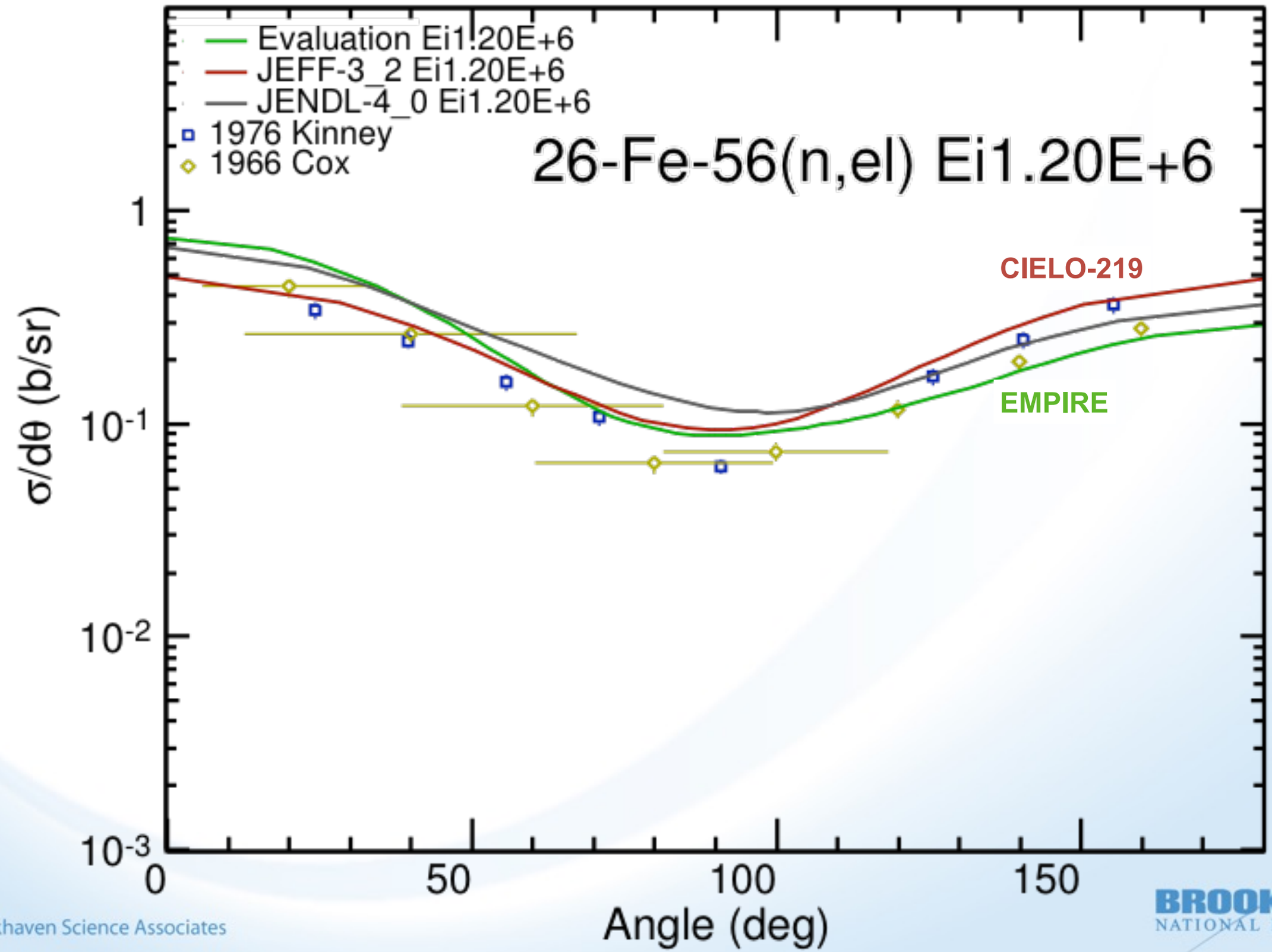
nat-Fe: Total, Elastic, Inelastic 2.00-2.50 MeV



Elastic angular distributions

- Kinney data are the most extensive and detailed above the inelastic threshold
- JEF-2.2=>JEFF-3.2 ang. distr. are fitted to the Kinney data
- Whenever low energy-resolution experimental data are available they are closer to EMPIRE than to Kinney
- However, RPI semi-integral experiment favors JEF(F)s so we adopted it between 846 keV and 4 MeV
- RPI broad-average data to be compared with EMPIRE and broad-averaged evaluations

Elastic angular distributions – Kinney data



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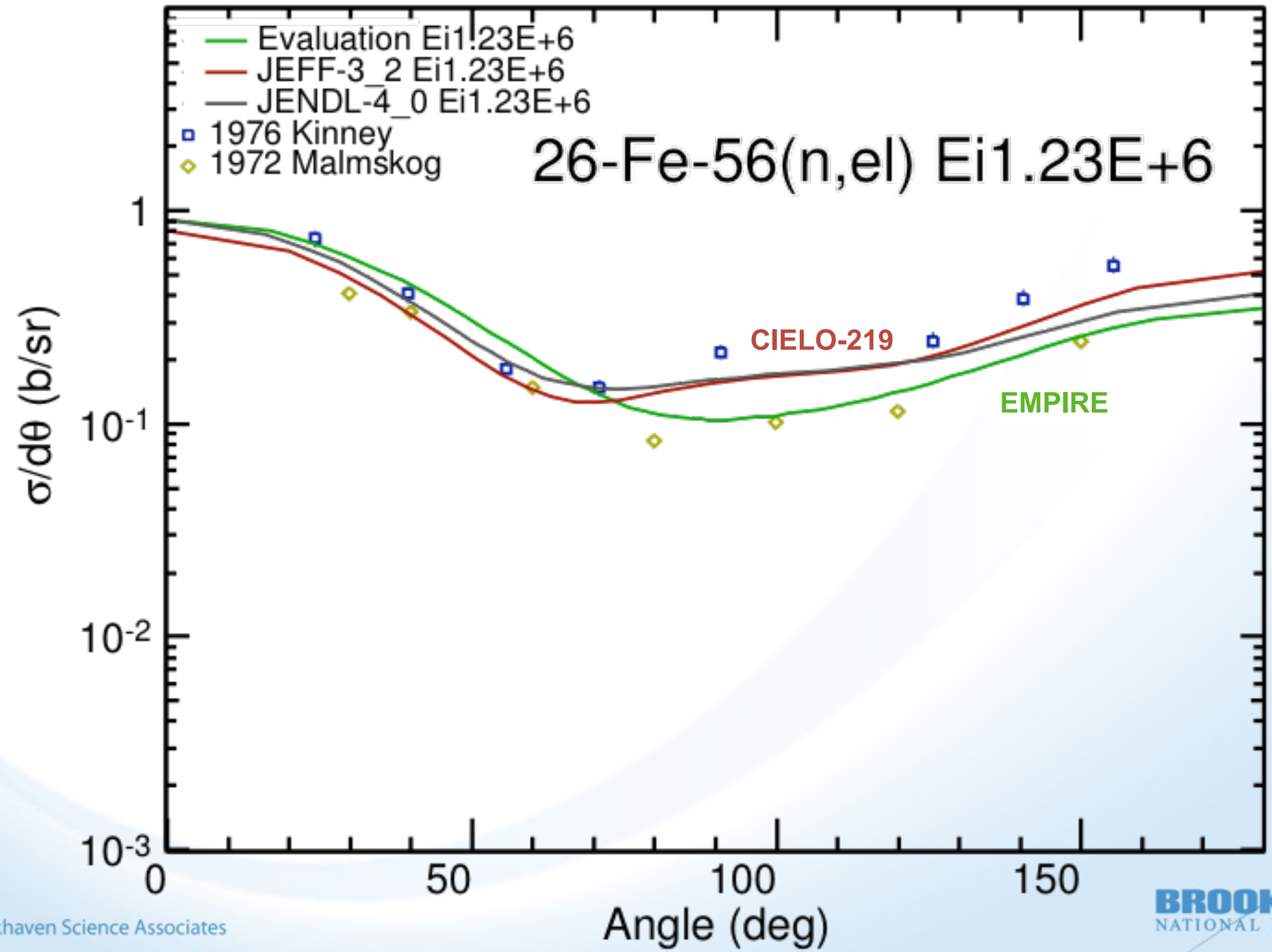

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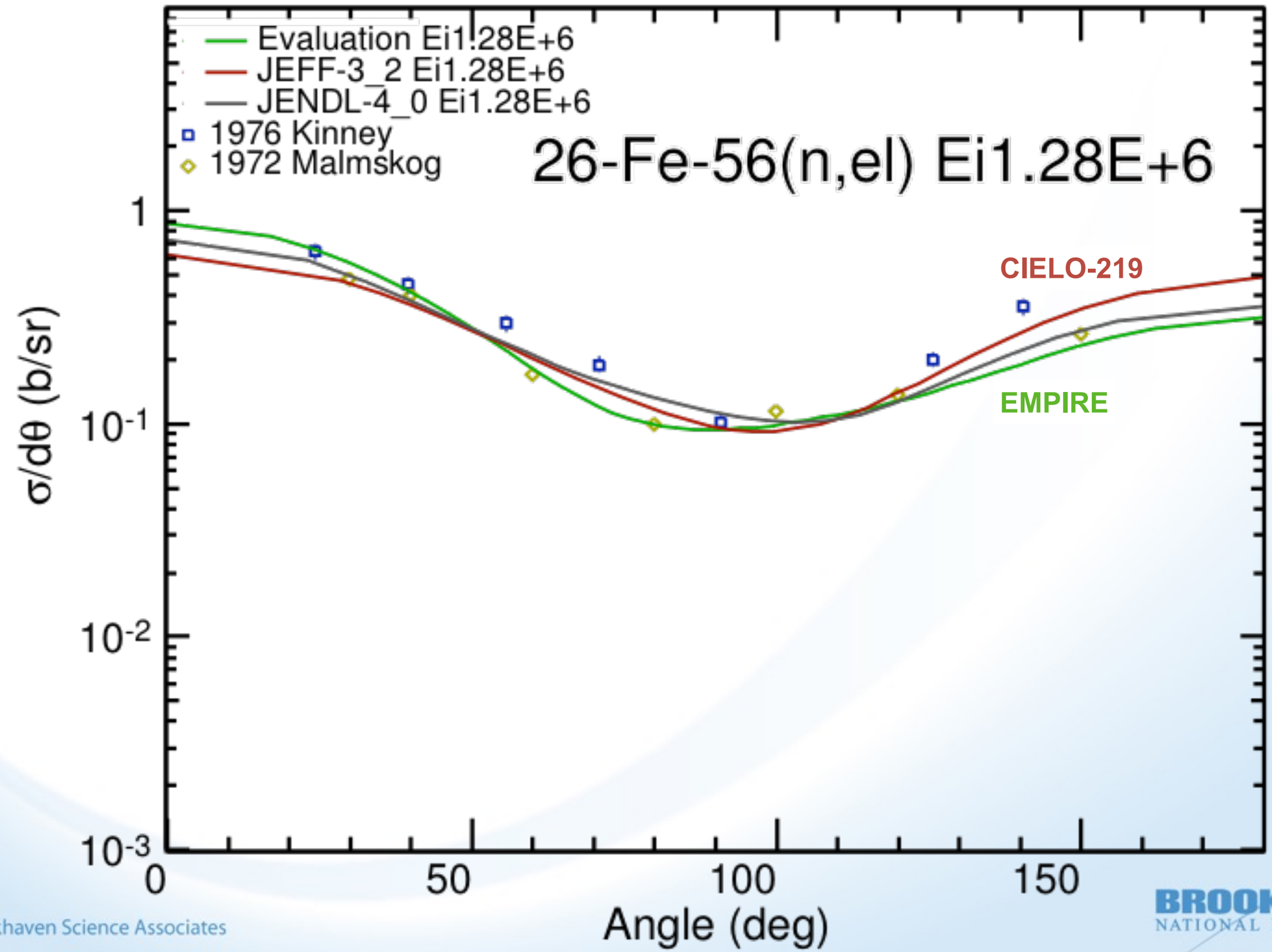

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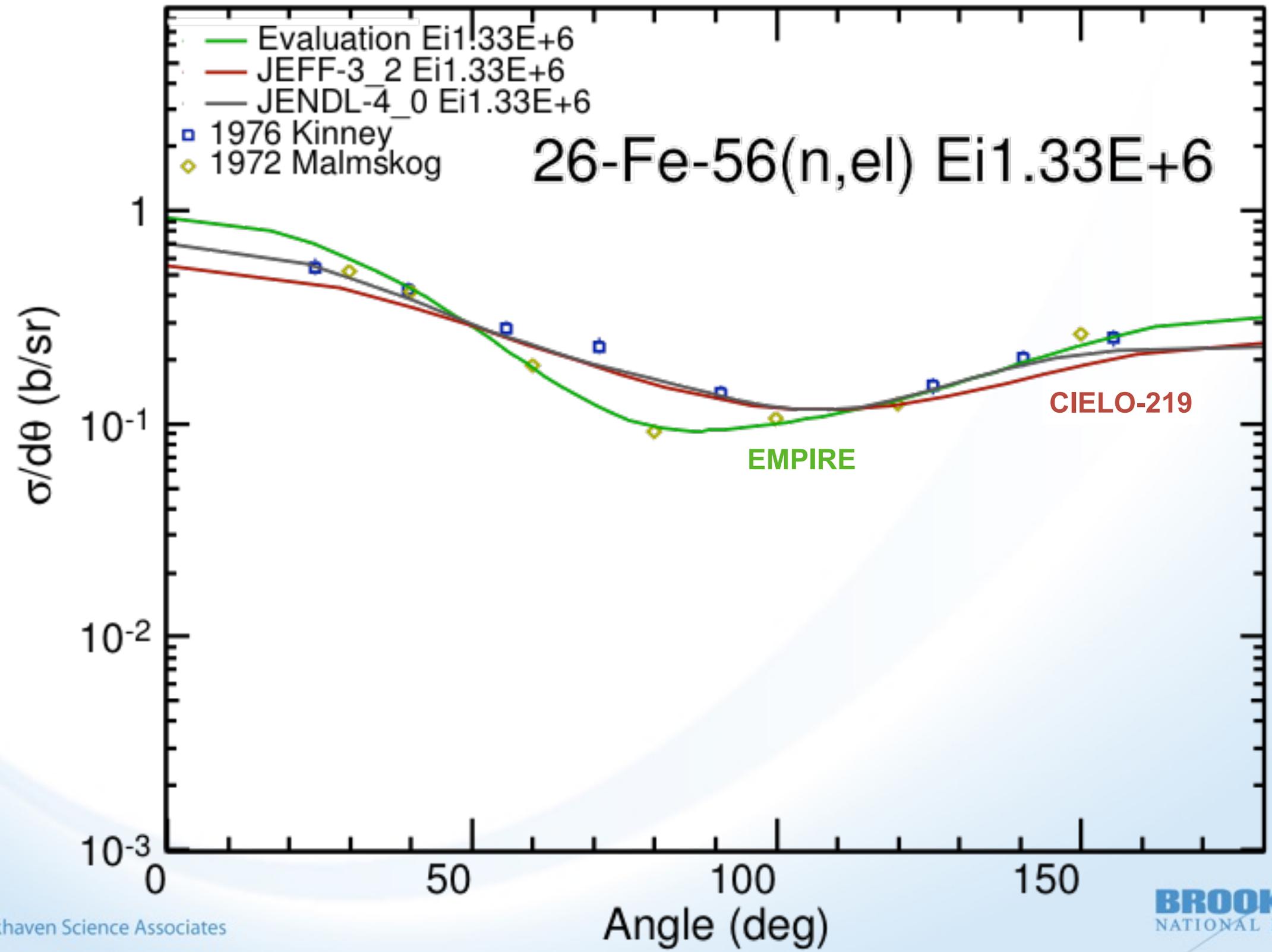

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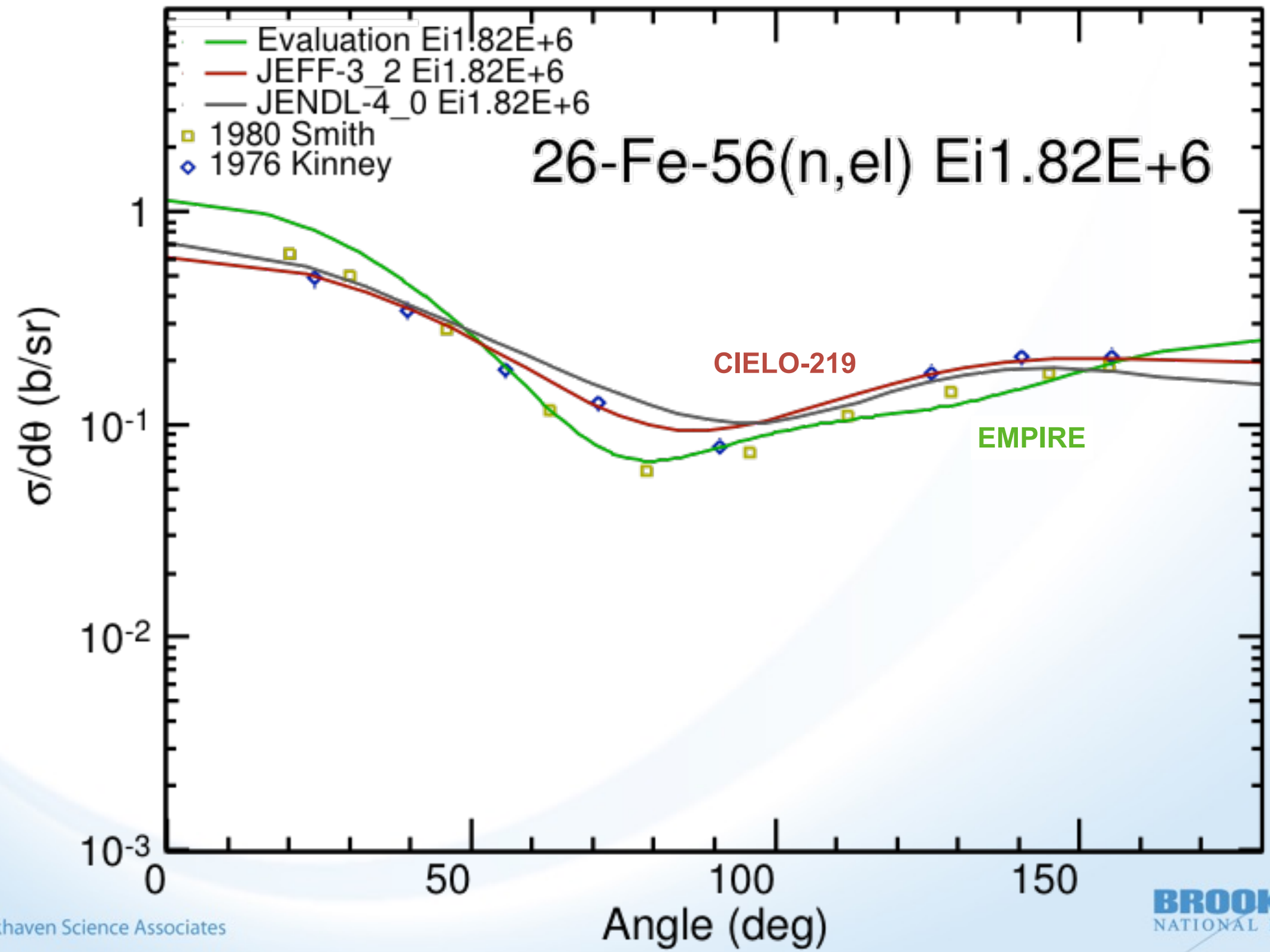

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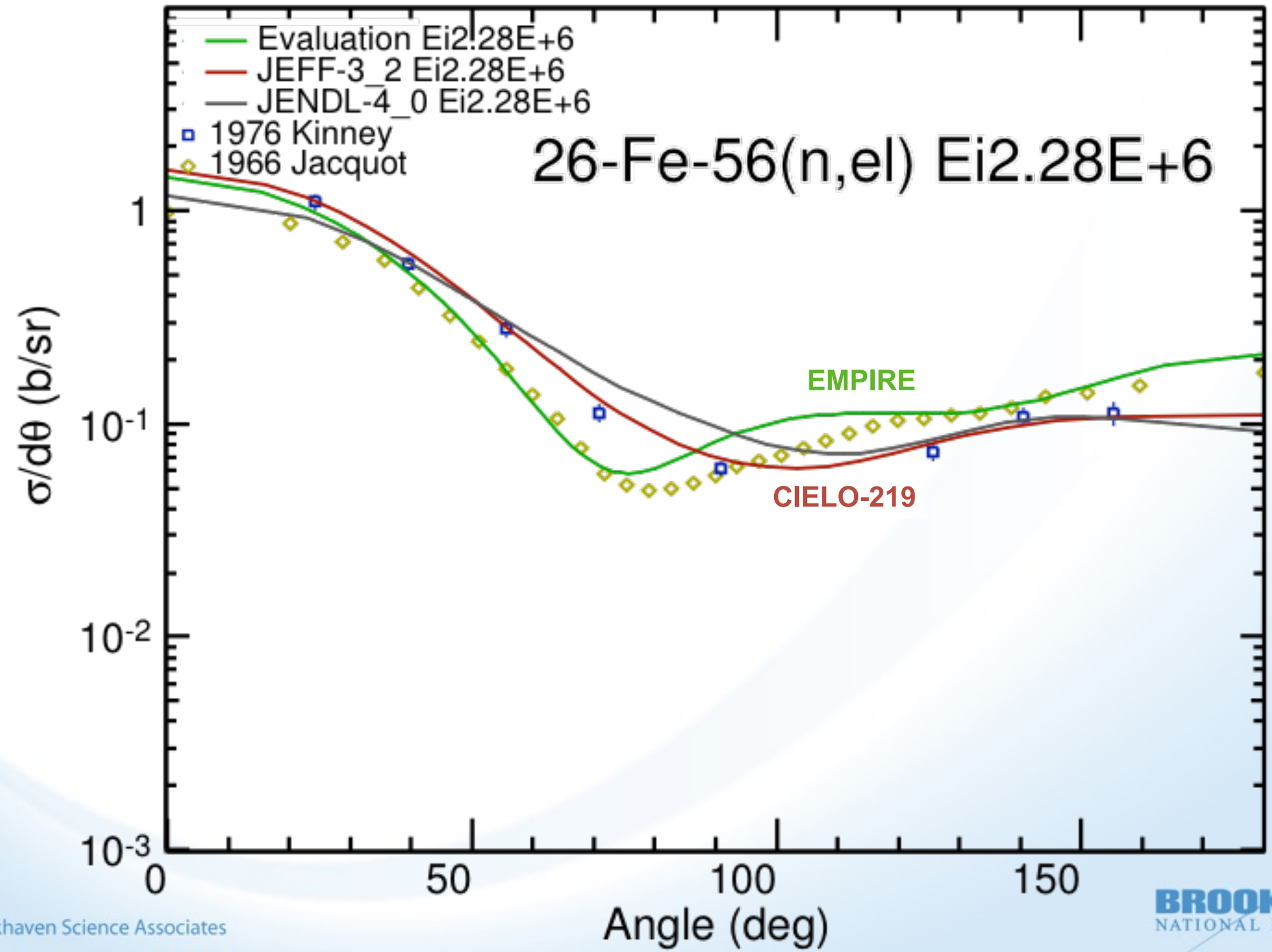

Summary of EMPIRE calculations (56Fe)

- CC for incident/outgoing channels + DWBA to uncoupled levels
- Lane-consistent soft-rotator dispersive OMP by Soukhovitski et al (PRC 2015)
- Rev. 88 replaces microscopic HFB level densities with Gilbert-Cameron (open issue of parity distribution)
- Width fluctuation correction (HRTW) up to 8 MeV (difference HRTW v. Moldauer <1%)
- Default gamma-ray strength function (Plujko MLO1)
- ~~TUL Multistep Direct >3 MeV plus Multistep Compound~~
- Exciton model (PCROSS) for PE emission including Iwamoto-Harada model for PE cluster emission: excellent reproduction of WNR hydrogen and helium production cross sections up to 100 MeV
- Rev. 88 fitted LD parameters to IRDFF for (n,p) and to experimental data for α production
- Rev. 219 energy range extended to 150 MeV
- Rev. 219 adds Kalman generated covariances in the fast region

Conclusions from the last CSEWG

- We've got fast neutron file that seems to fit differential data (subject to RPI validation though!) - still true but… for a different file!
- We still do not have clear picture in the RR: still holds
  - how far to go (846 keV versus 2 MeV)? 846 keV
  - although VII.1 RR wins 'beauty contest' in crits we can't use it still holds
  - what elastic angular distributions to use?
    - constructed from resonance parameters (tempting) still tempting
    - fit to Perey and Kinney data (JEFF-3.2) (not always the best choice) did it in rev.219 but between end of RR and 4 MeV
    - JENDL-4.0, which seems to be smoothed results from resonance parameters (our choice in RR in rev.88) and in rev.219
    - OMP - increases reactivity for several fast crits (right direction) if applied in RR but irons out all fluctuations (rev.88 uses it above 846 keV) rev.219 above 4 MeV
- Elastic angular distr. and capture can be used to improve agreement with benchmarks, however… we need the full CIELO library

Never has been more true

Steps planned at CSEWG. Where we are? Where we go?

- Perform fine tuning to differential data (if needed) hopefully cosmetics
- Extend energy range to 150 MeV done!
- Extend evaluation to other isotopes in ^{nat}Fe done!
- Validate new *set* of files continuing…
- Perform adjustment to the integral data (if needed) we are still not there
- New evaluations of Fe minor isotopes have been produced
- 56Fe has been revisited based on RPI feedback (RPI data extremely important again for Fe-56). Fluctuations have been empirically considered both in total and inelastic (from data), and especially in angular distributions (following Kinney experiment).
- Additional information may still be extracted based on RPI data (e.g., capture on Fe-56 tuned above 846 keV, inelastic to elastic ratio and angular dependence improved)

…and where we go?

- Additional information may still be extracted based on RPI data (e.g., capture on Fe-56 tuned above 846 keV, inelastic to elastic ratio and angular dependence improved)
- Angular distributions from res. param.
- Parity distributions in level densities (likely part of the cosmetics)
- Additional work needed for SS non-iron components (e.g., Cr)
- Major problem - modern & reliable set of RR parameters for 56Fe without background, but with angular distributions; most likely won't happen

Said:

- "The only new measurement of resonance parameters since 2005 is that of CERN…
- CERN capture kernels agree with the ORNL and GEEL results very good…
- resonance capture widths are well determined… no change from values reported in the ATLAS…
- **however**, in the Reich- Moore formalism fictitious strong levels are required and are imposed above the upper energy region"