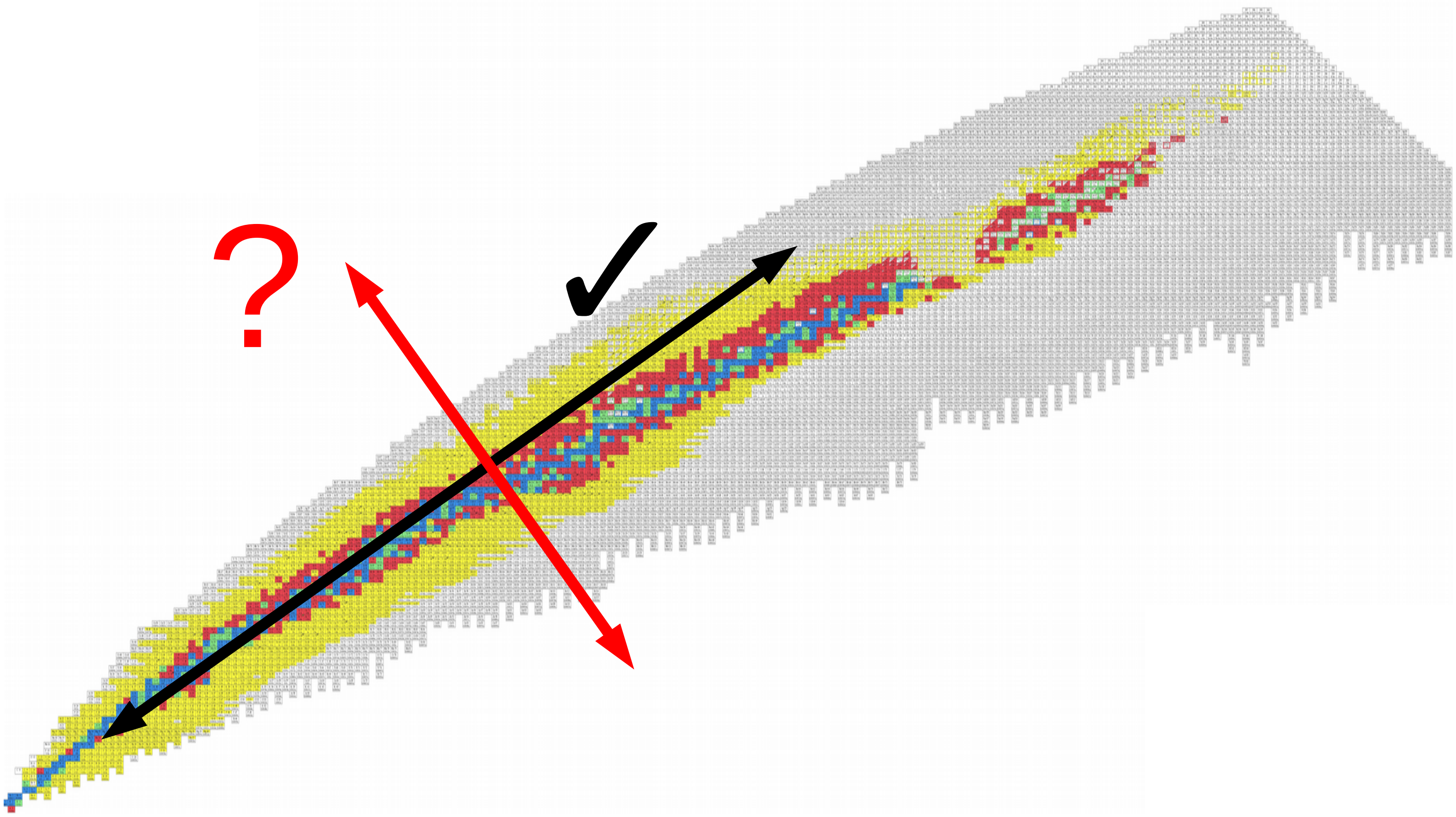
Isotopically-separated Neutron Total Cross Sections as Probe for Nuclear Properties



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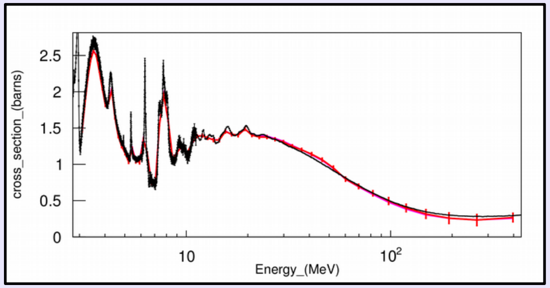
Outline

1

The Dispersive Optical Model (DOM) and physics motivation

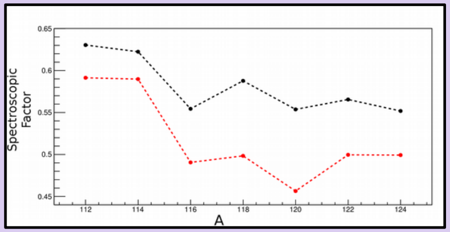
2

^{112,124}Sn/^{16,18}O $\sigma_{n,tot}$ and ^{112,124}Sn $d\sigma_n/d\Omega$ experimental results



3

DOM fit status and next steps: Ni $\sigma_{n,tot}$



The Dispersive Optical Model

- Construct a ***complex optical potential*** for nucleon-nucleus interaction (with analogy to optical scattering).
- In the DOM, ***real part*** *(elastic scattering) and* ***imaginary part*** *(inelastic scattering) of potential* ***are inextricably coupled***, via Kramers-Kronig relations, just as in optical case.
- Generating a good DOM fit potential requires both scattering *and* bound state information.

parameterize optical potential

fit to existing data

extract self-energy

calculate properties (spectroscopic factor, neutron skin, etc.)

$$G(\alpha,\beta;E) = G^{(0)}(\alpha,\beta;E) + \sum_{\gamma,\delta} G^{(0)}(\alpha,\gamma;E)\Sigma(\gamma,\delta;E)G(\delta,\beta;E).$$

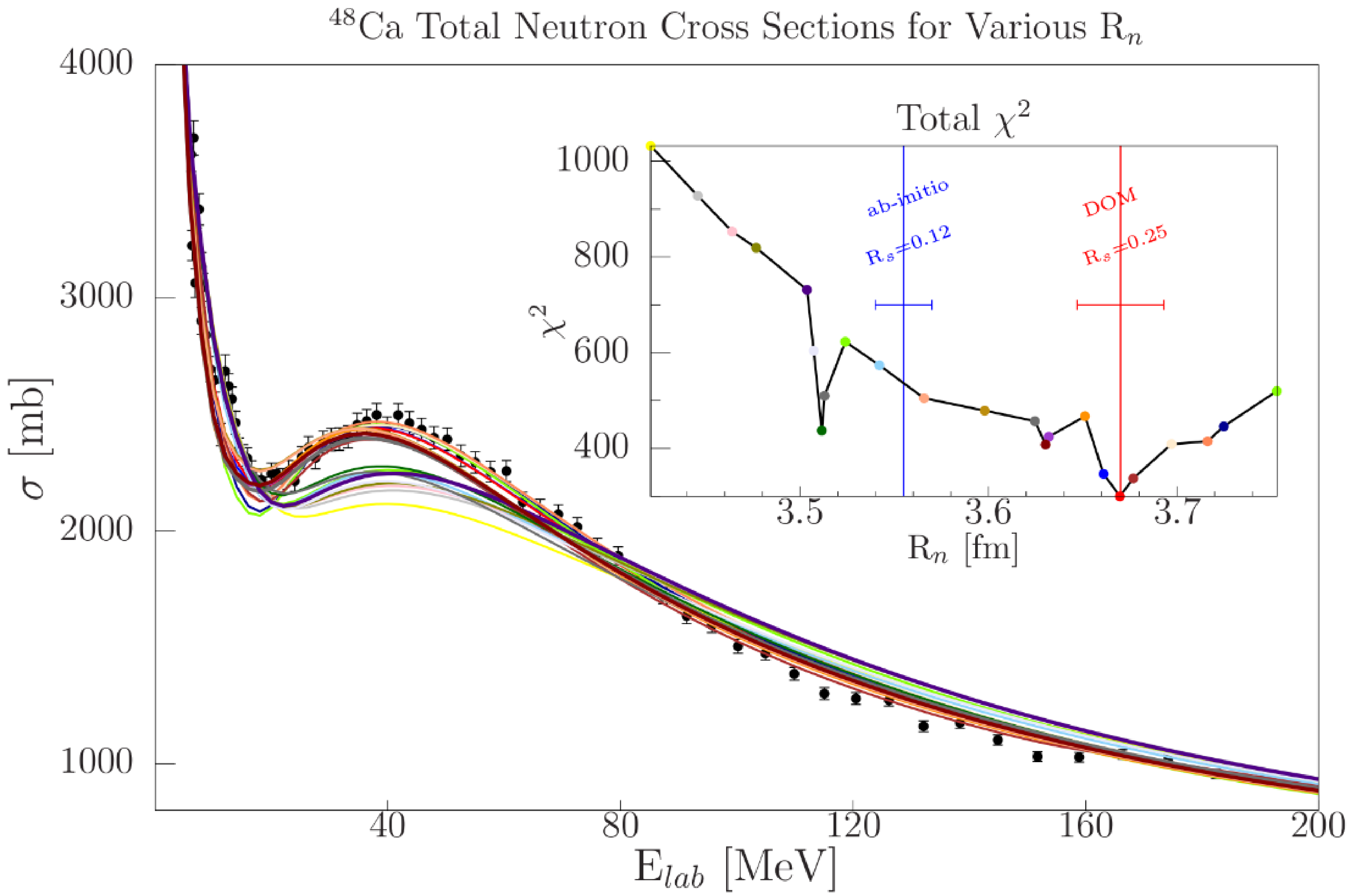
propagator — $G(\alpha,\beta;E)$

Non-interacting propagator — $G^{(0)}(\alpha,\beta;E)$

self-energy — $\Sigma(\gamma,\delta;E)$

"Novel Applications of the Dispersive Optical Model": Dickhoff, Charity, Mahzoon (2016)

Extracting a neutron skin using $\sigma_{tot}(^{48}Ca)$

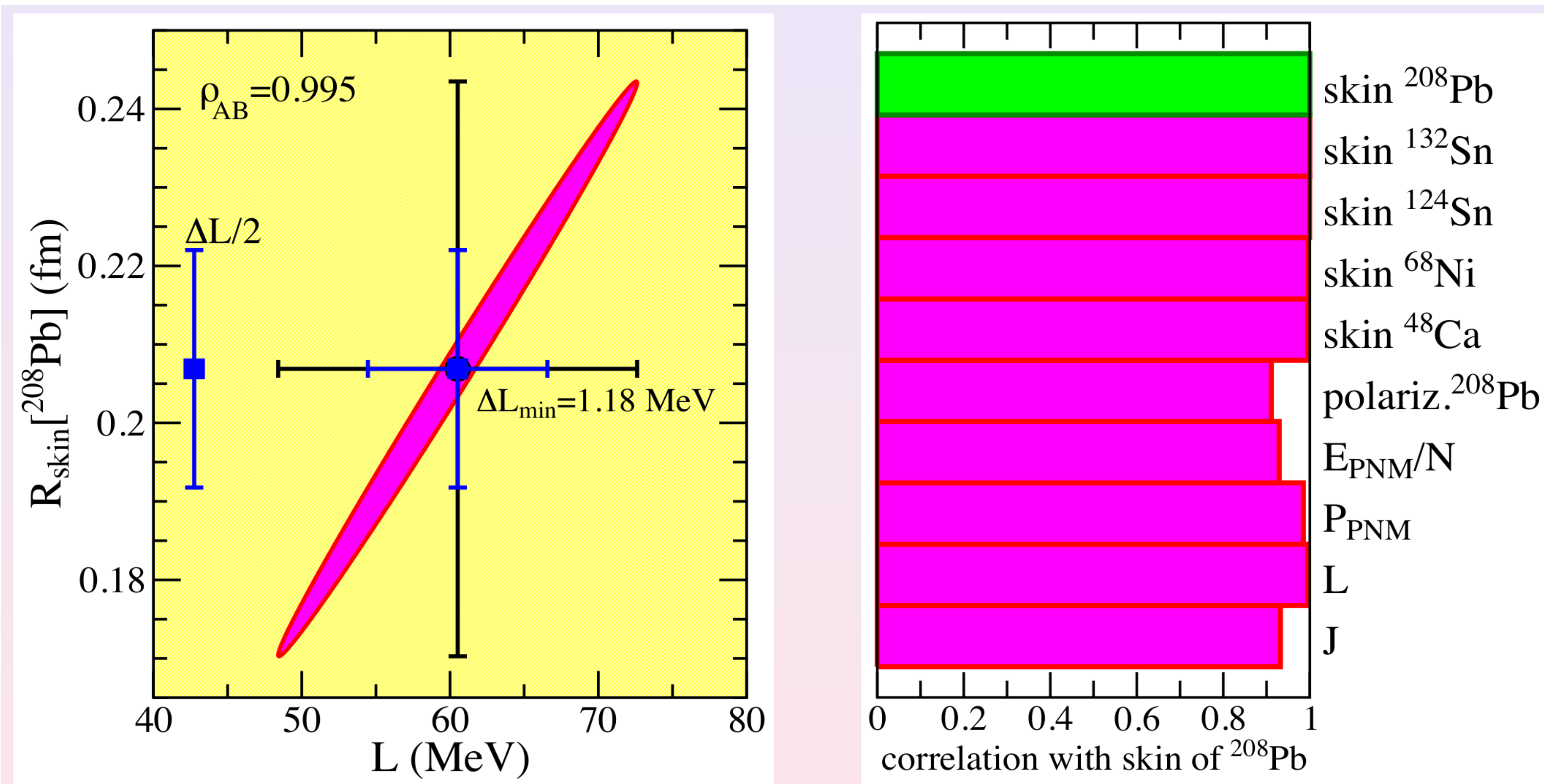


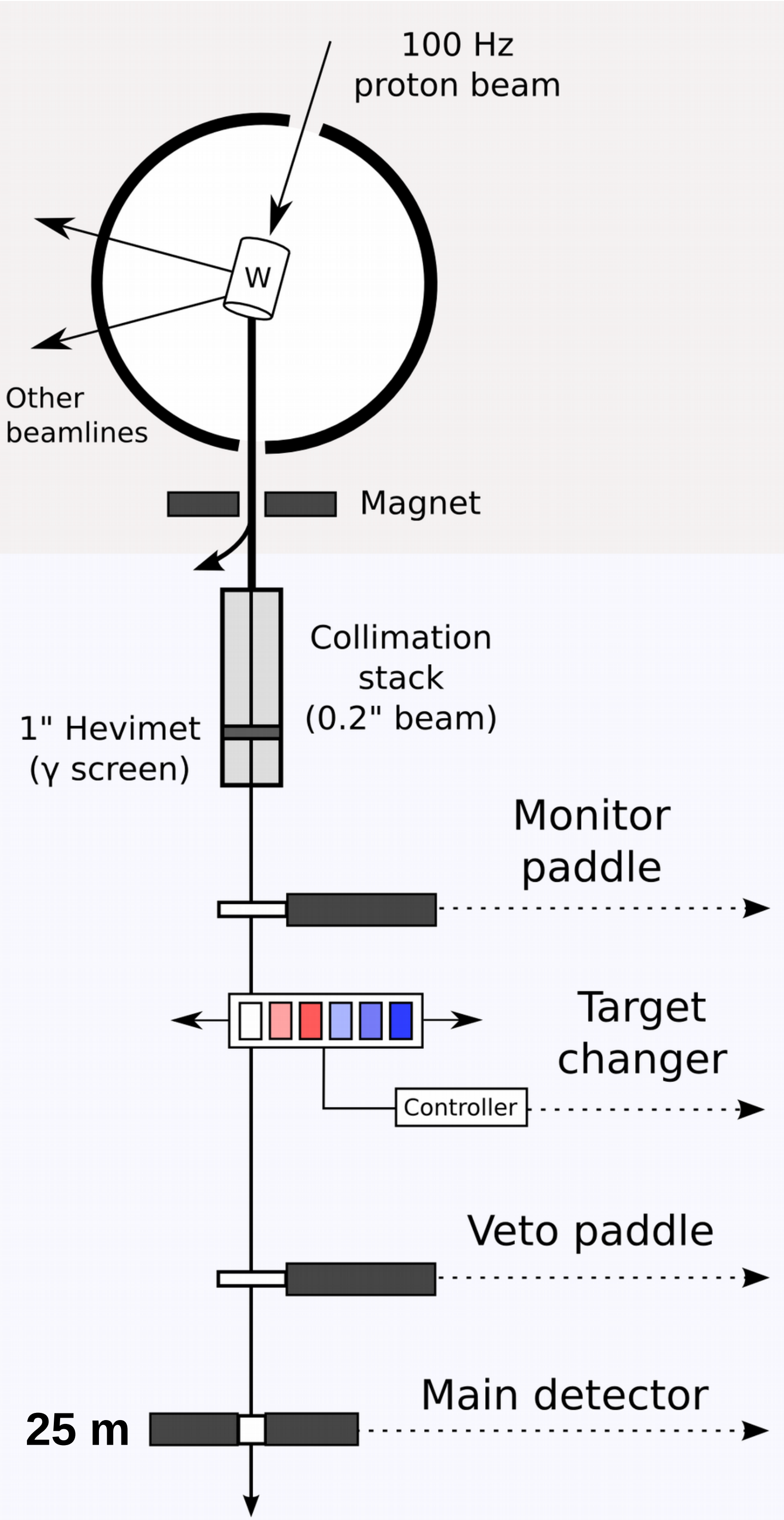
Neutron star EOS $\Leftrightarrow$

???

$$S(\rho) \simeq S(\rho_0) - L\left(\frac{\rho_0-\rho}{3\rho_0}\right) + \frac{1}{2}K_{sym}\left(\left(\frac{\rho_0-\rho}{3\rho_0}\right)^2\right)$$

"The correlation between **neutron radius of ^{208}Pb and the slope of the symmetry energy L** is by now very well established..."
- F. J. Fattoyev and J. Piekarewicz, PRC 86 015802 (2012)





Measuring σ_{tot} on a budget

- LANSCE WNR at Los Alamos:
  i. W-spallated broad-spectrum neutrons (up to 650 MeV)
  ii. intricate beam pulse structure (needed for TOF)
- Experimental details:
  i. Neutron energies calculated by TOF
  ii. location of stopping detector create a tradeoff between determines minimum energy and pile-up at high energies
  iii. high instantaneous flux at the start of a new neutron pulse is 90% of the difficulty
  iv. waveform digitizer used instead of traditional analog approach

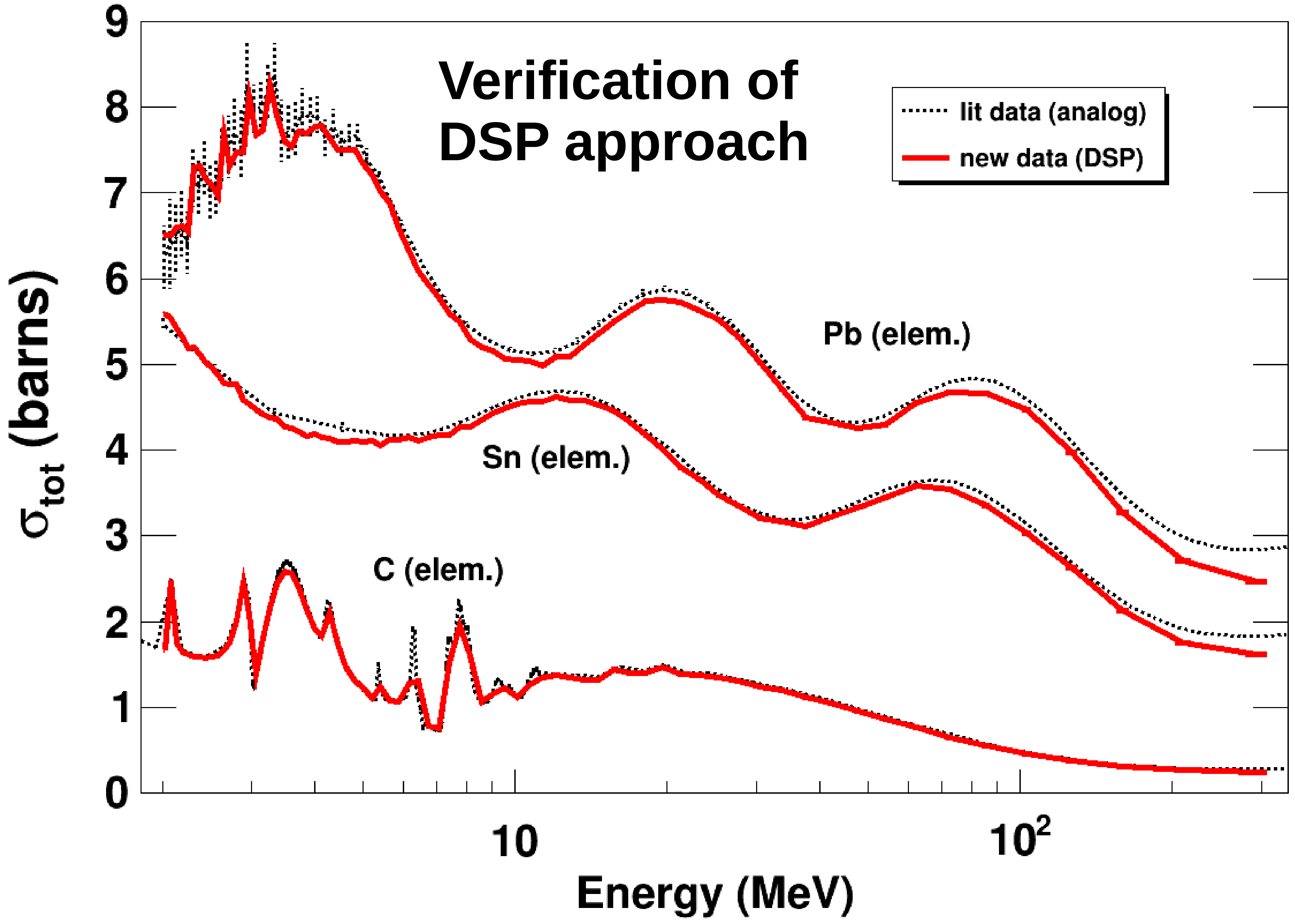
DSP has 20x deadtime advantage

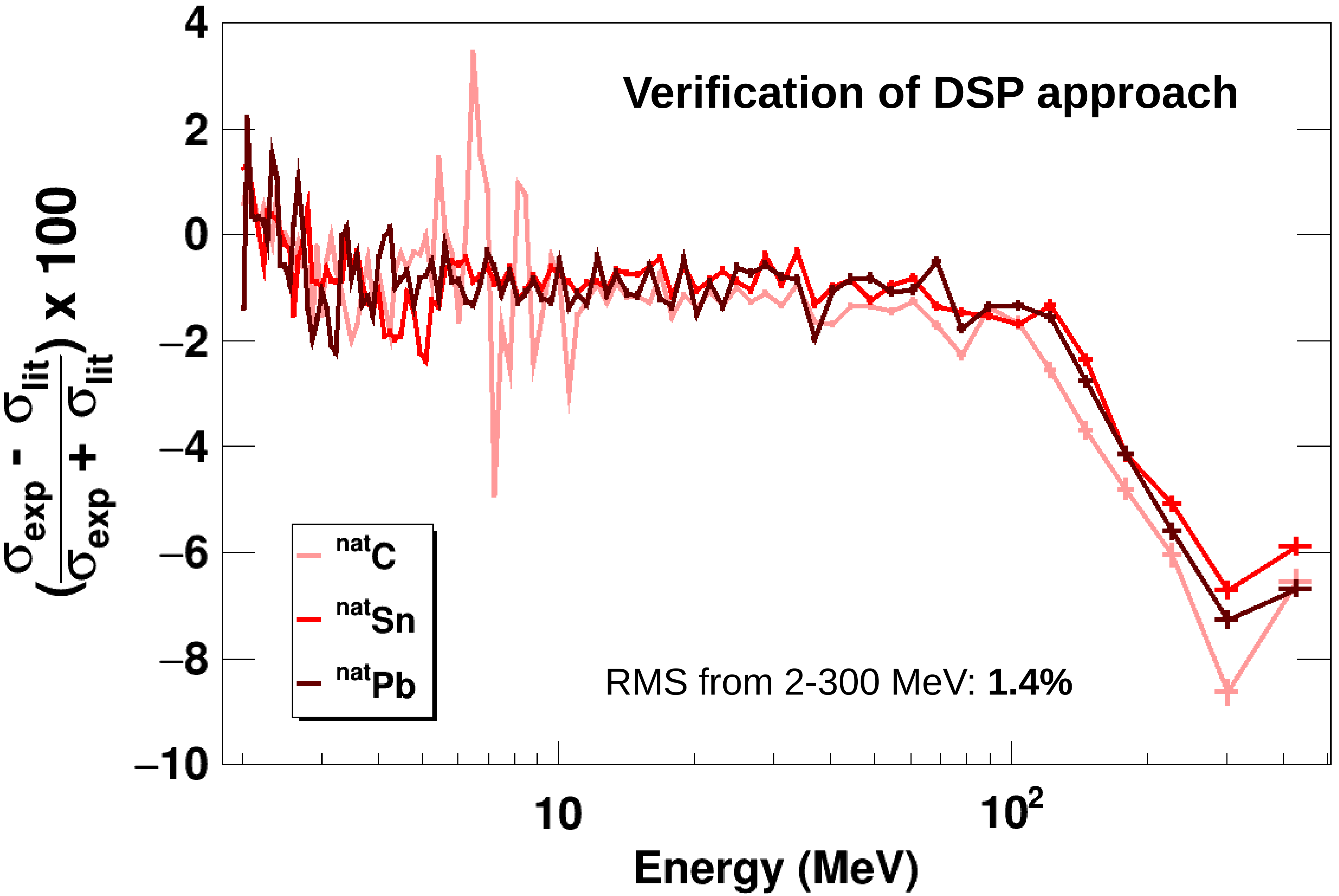
⇓

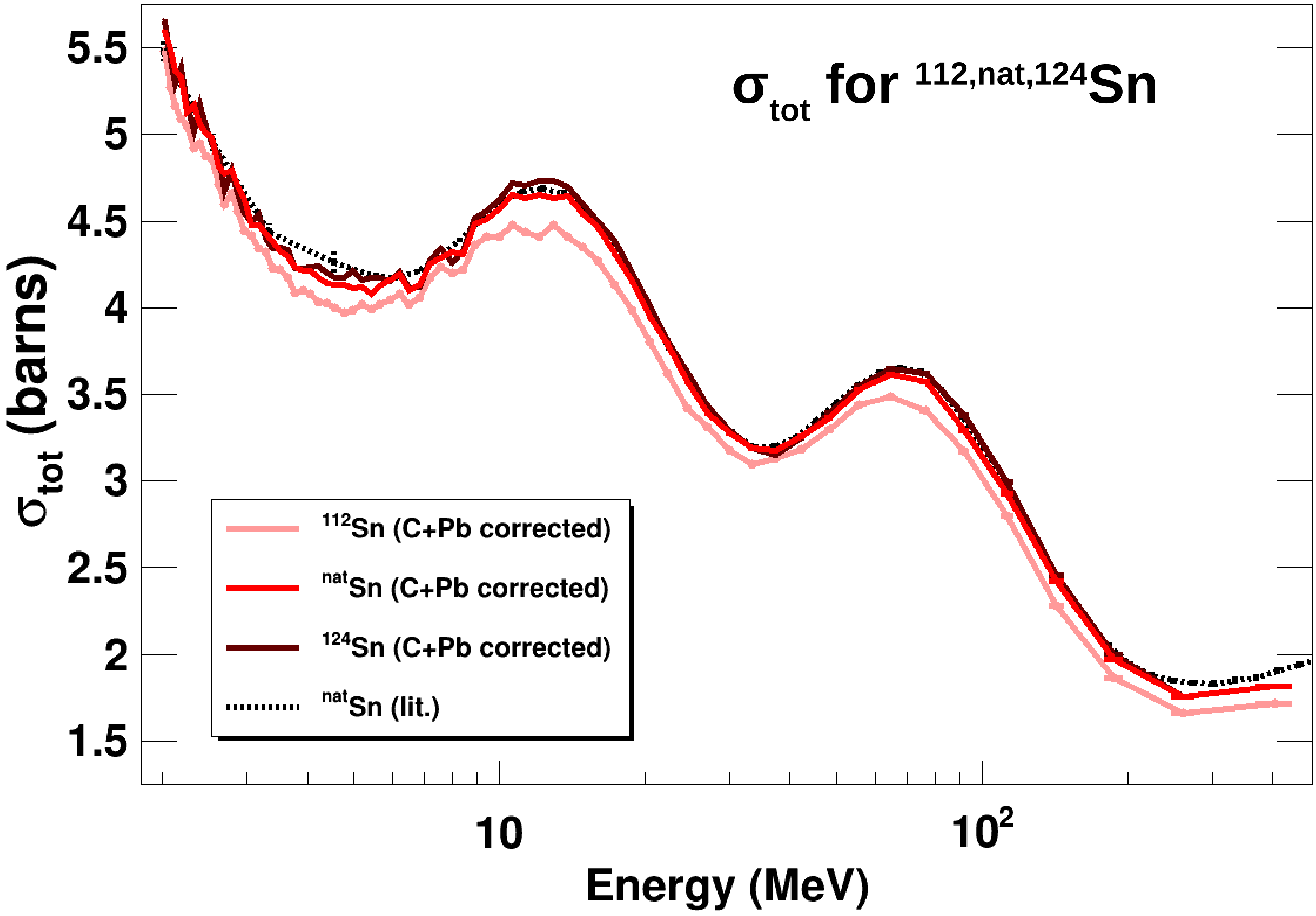
20x reduction in target size

⇓

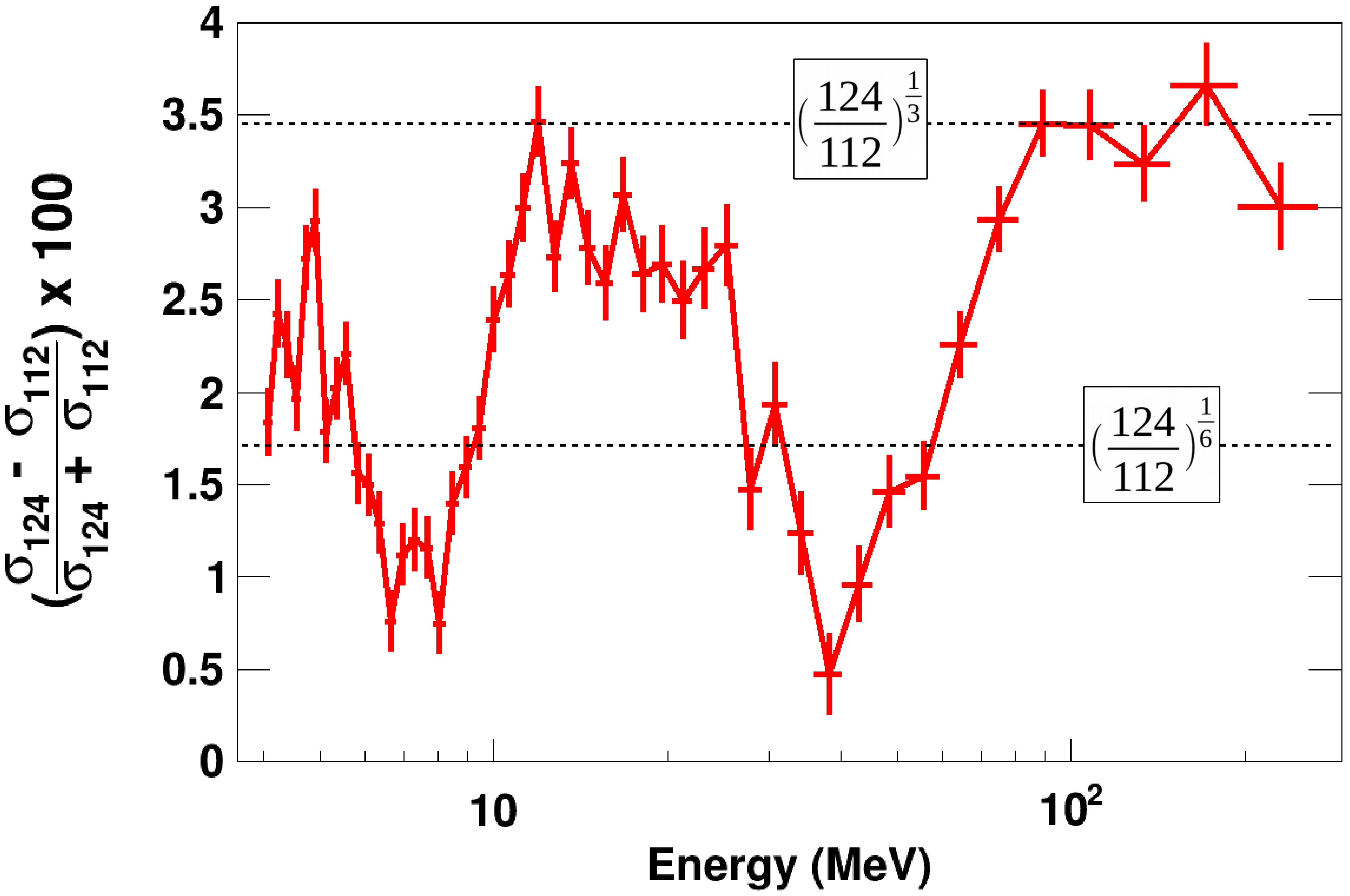
experiment is affordable


Verification of
DSP approach
lit data (analog)
new data (DSP)
Pb (elem.)
Sn (elem.)
C (elem.)
σ_{tot} (barns)
Energy (MeV)
0
1
2
3
4
5
6
7
8
9
10
10^2

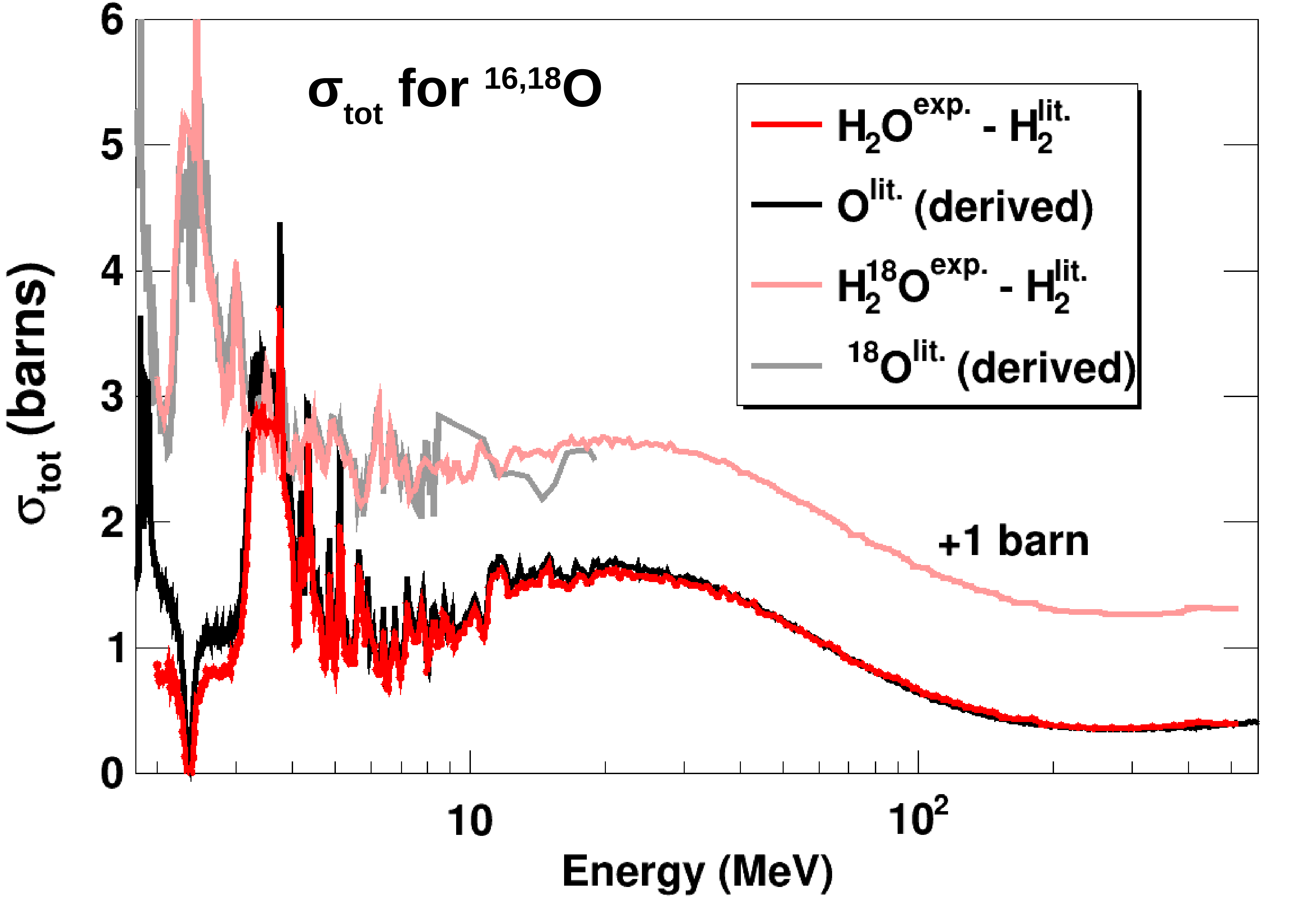

Verification of DSP approach
RMS from 2-300 MeV: **1.4%**
natC
natSn
natPb
$(\frac{\sigma_{exp} - \sigma_{lit}}{\sigma_{exp} + \sigma_{lit}}) \times 100$
4
2
0
−2
−4
−6
−8
−10
10
10^2
Energy (MeV)

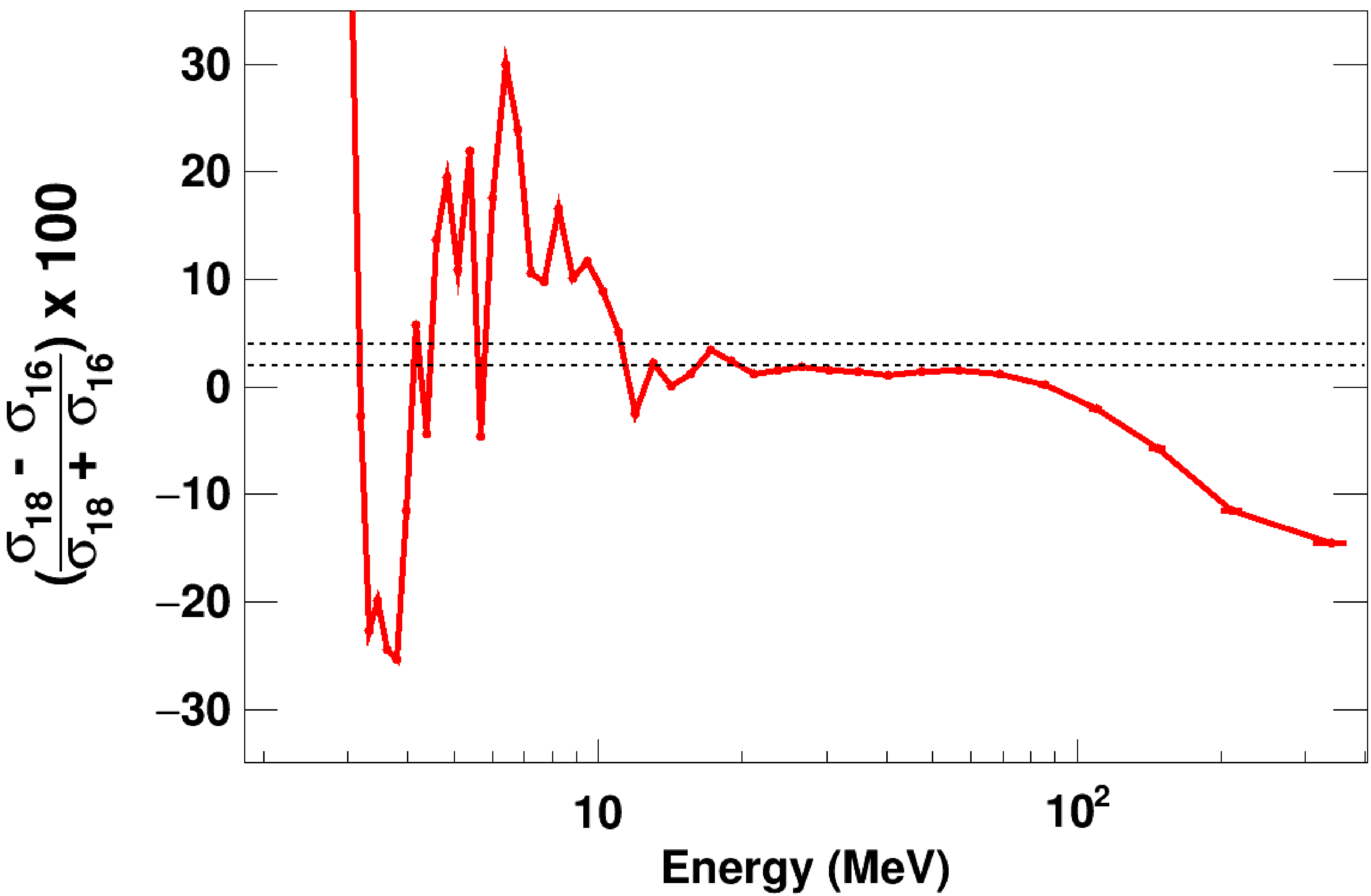


σ_{tot} for $^{112,nat,124}Sn$
σ_{tot} (barns)
5.5
5
4.5
4
3.5
3
2.5
2
1.5
^{112}Sn (C+Pb corrected)
^{nat}Sn (C+Pb corrected)
^{124}Sn (C+Pb corrected)
^{nat}Sn (lit.)
10
10^2
Energy (MeV)

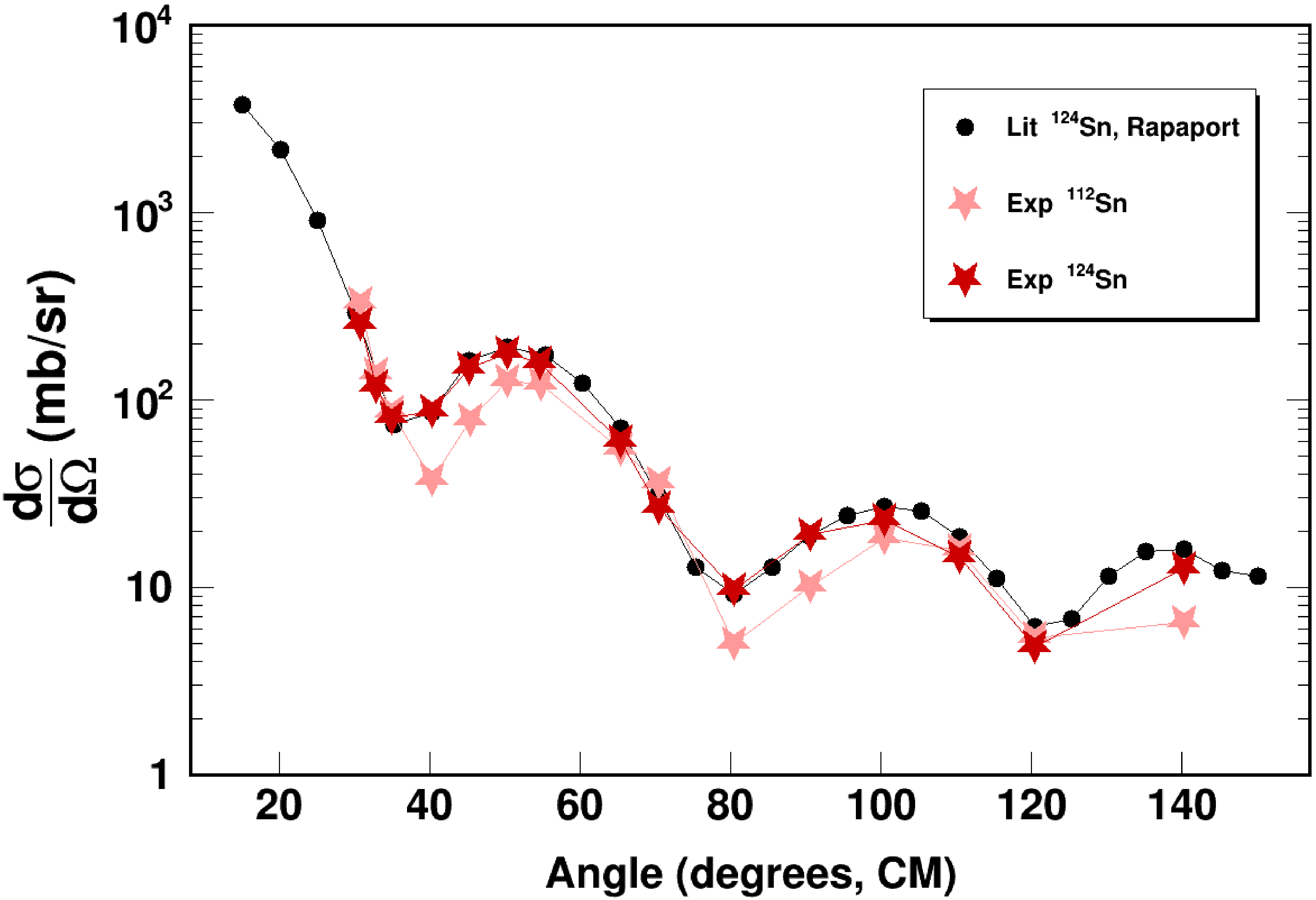


$(\frac{\sigma_{124} - \sigma_{112}}{\sigma_{124} + \sigma_{112}}) \times 100$
4
3.5
3
2.5
2
1.5
1
0.5
0
10
10^2
Energy (MeV)
$(\frac{124}{112})^{\frac{1}{3}}$
$(\frac{124}{112})^{\frac{1}{6}}$

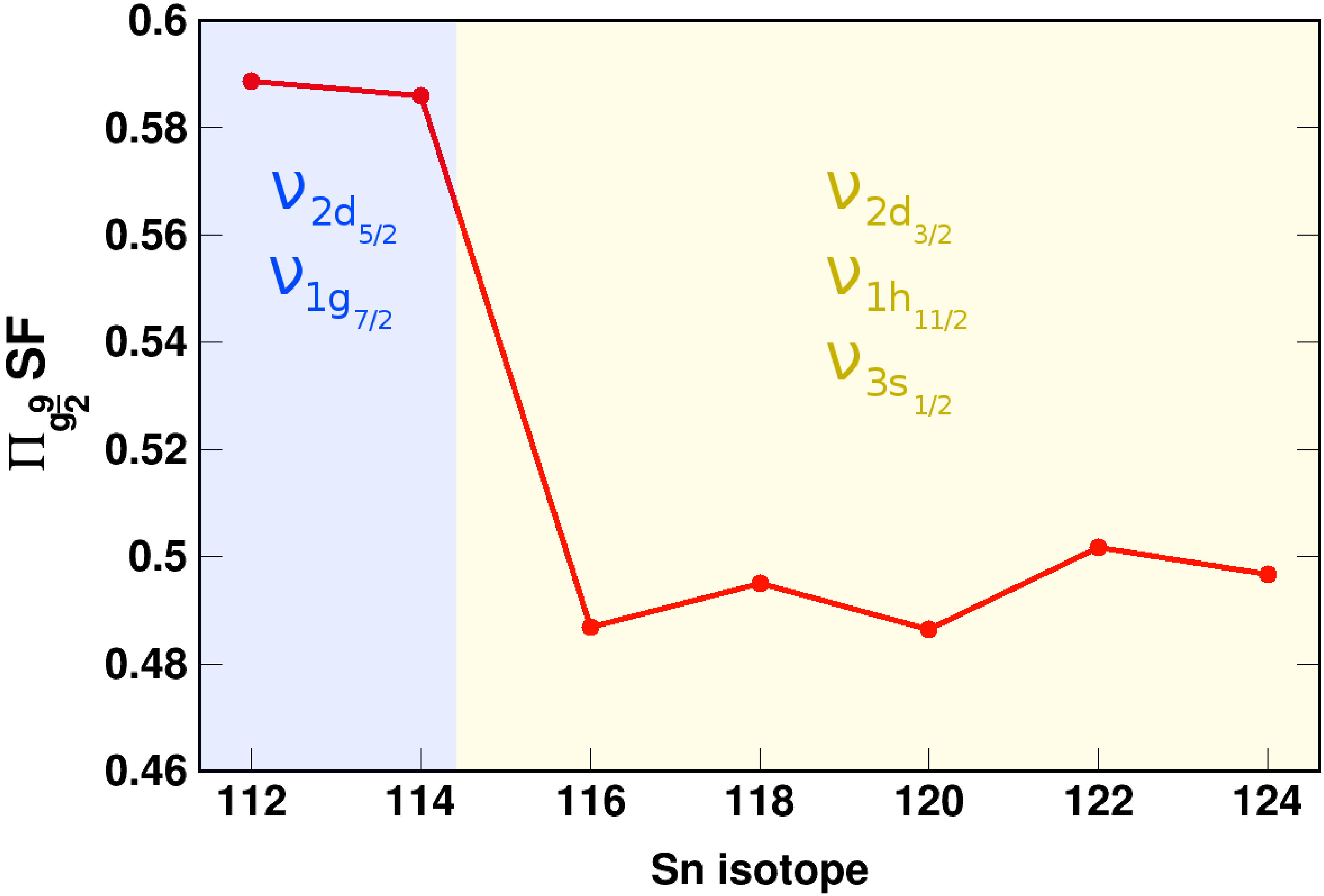

σtot for 16,18O
H2Oexp. - H2lit.
Olit. (derived)
H218Oexp. - H2lit.
18Olit. (derived)
+1 barn
σtot (barns)
Energy (MeV)
0
1
2
3
4
5
6
10
10^2



30
20
10
0
−10
−20
−30
10
10^2
Energy (MeV)
$\left(\frac{\sigma_{18} - \sigma_{16}}{\sigma_{18} + \sigma_{16}}\right) \times 100$



Lit ^{124}Sn, Rapaport
Exp ^{112}Sn
Exp ^{124}Sn
$\frac{d\sigma}{d\Omega}$ (mb/sr)
Angle (degrees, CM)
10^4
10^3
10^2
10
1
20
40
60
80
100
120
140


0.6
0.58
0.56
0.54
0.52
0.5
0.48
0.46
$\Pi_{g\frac{9}{2}}$ SF
$\nu_{2d_{5/2}}$
$\nu_{1g_{7/2}}$
$\nu_{2d_{3/2}}$
$\nu_{1h_{11/2}}$
$\nu_{3s_{1/2}}$
112
114
116
118
120
122
124
Sn isotope

Next steps

- New experiment: ^{58,64}Ni at LANSCE (*in Sept*)
- Adapt ^{40}Ca DOM code for O, Ni, and Sn (*ongoing*)
  - first bring symmetric version online, then introduce asymmetry parameters
- Last, “tune in” a good DOM fit for each nucleus
  - extracting neutron skins -> L; cf. *REX measurements, (motivating SREX?)
  - extract spectroscopic factors; cf. (e,e'p) experiment comparison for O.

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