systematic studies of beam normal single-spin asymmetries at MAMI

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on behalf of the A1 collaboration
Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

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on Nuclear Physics
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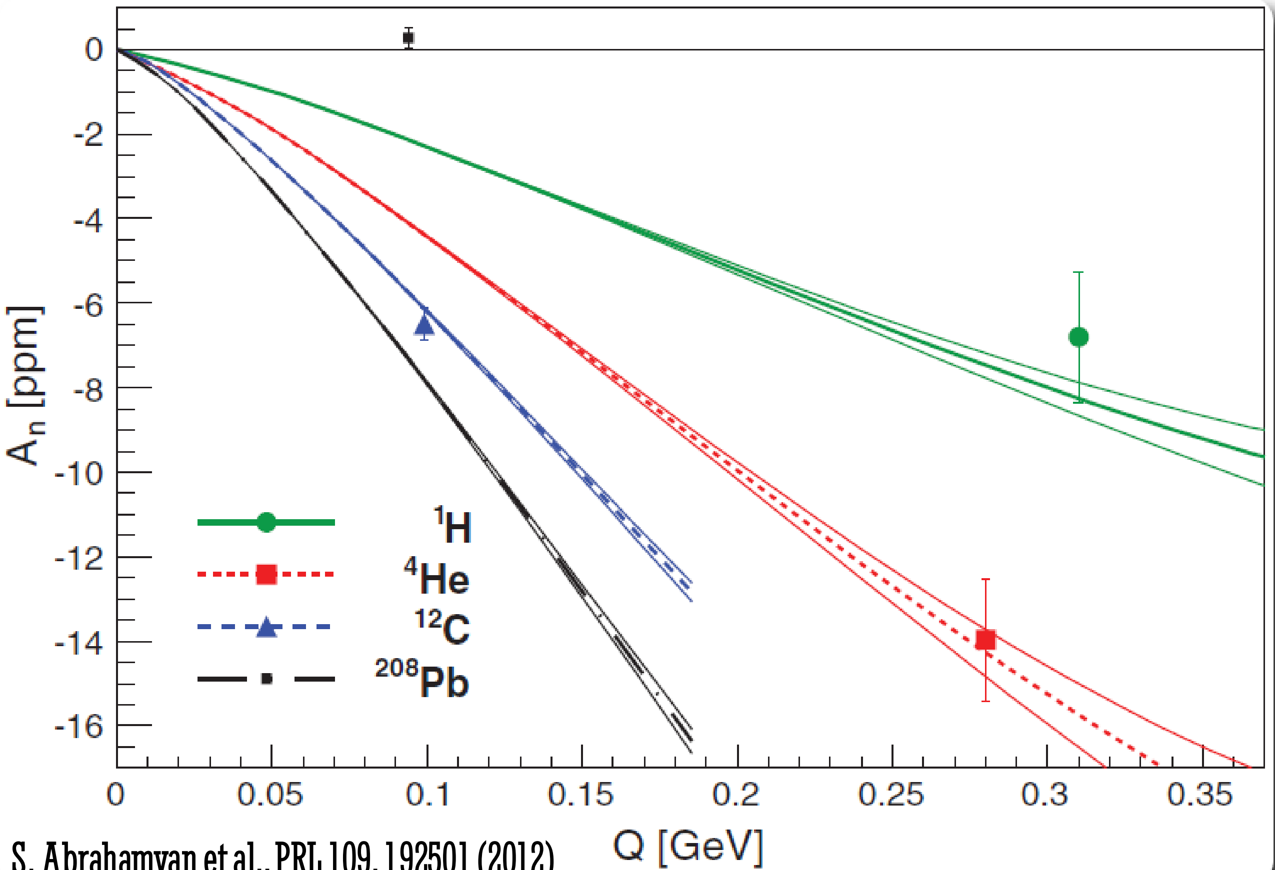
JG|U SFB 1044 PRiSMA

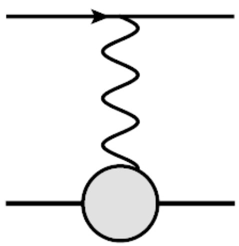
being more precise: boon and bane



S. Abrahamyan et al., PRL 109, 192501 (2012)

elastic electron scattering

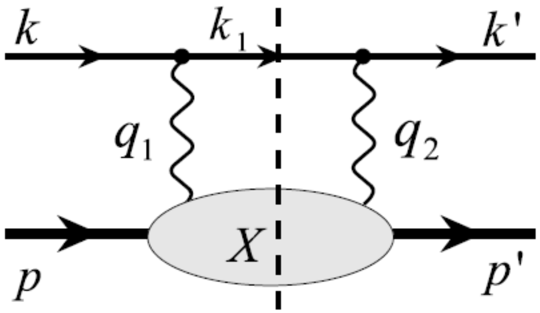
one-photon exchange



purely real

+

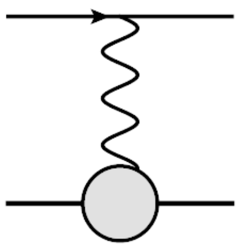
two-photon exchange



has imaginary part

elastic electron scattering

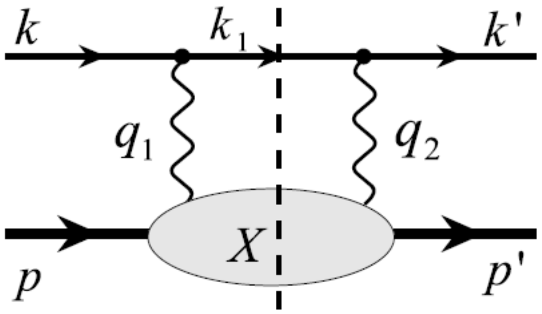
one-photon exchange



purely real

\+

two-photon exchange



has imaginary part

beam normal single-spin asymmetry A_n:

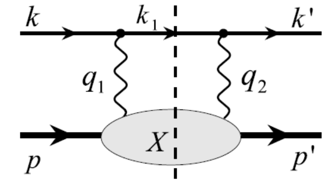
arises from interference of one- and two-photon exchange

De Rújula et al., Nucl. Phys. B35, 365 (1971)

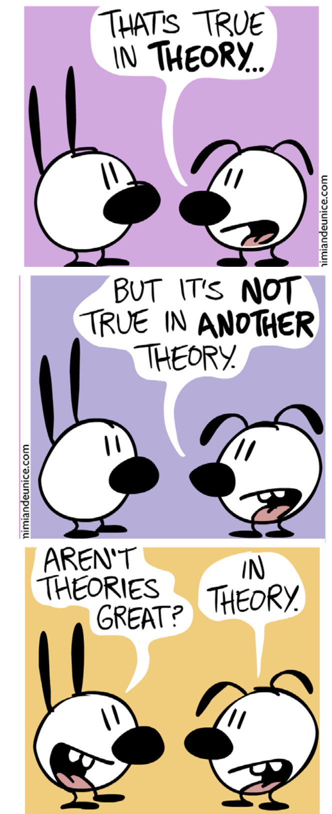
allows access of imaginary part of 2γ exchange amplitude

theoretical treatment of A_n

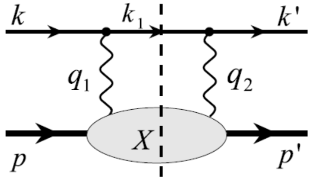
consider contributions of elastic (scales as Z)
AND inelastic intermediate states (scales as A/Z)



dispersion integral over intermediate excited states



theoretical treatment of A_n



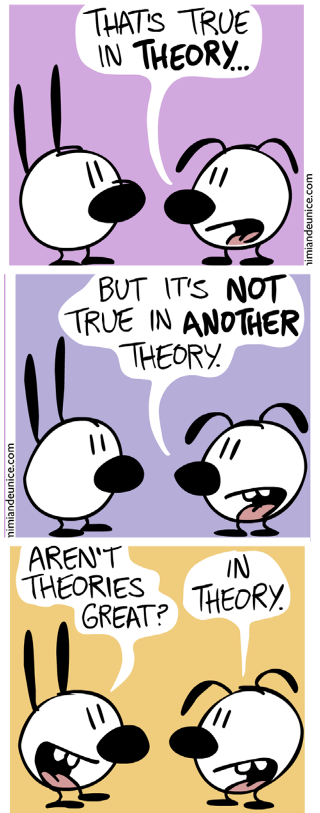
consider contributions of elastic (scales as Z)
AND inelastic intermediate states (scales as A/Z)

dispersion integral over intermediate excited states

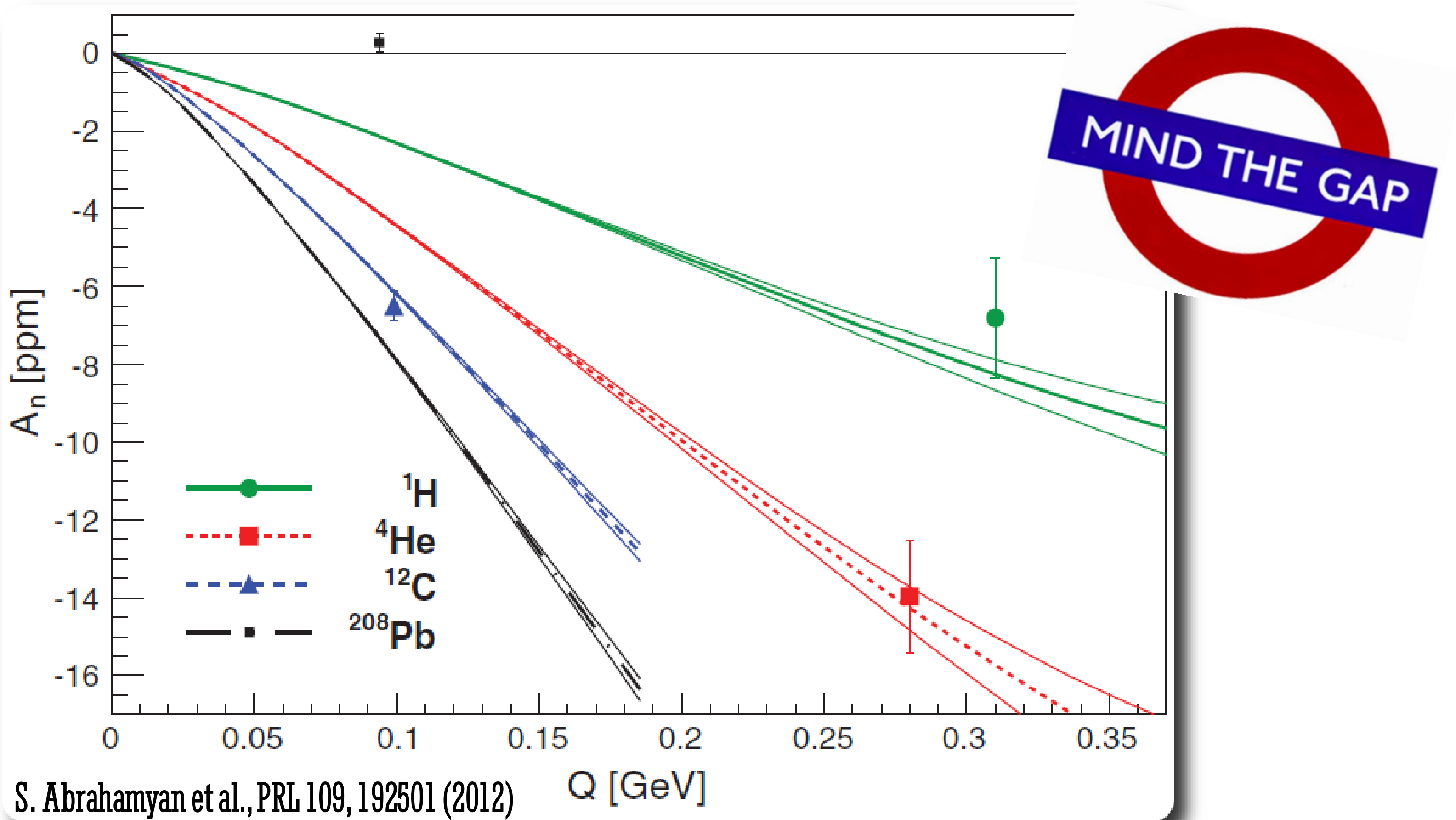
focus on very low four-momentum transfer:
leading order ~ $C_0 \cdot \log(Q^2/m^2)$ Gorchtein and Horowitz, Phys. Rev. C77, 044606 (2008)

C_0 contains energy dependence

can be calculated exactly!

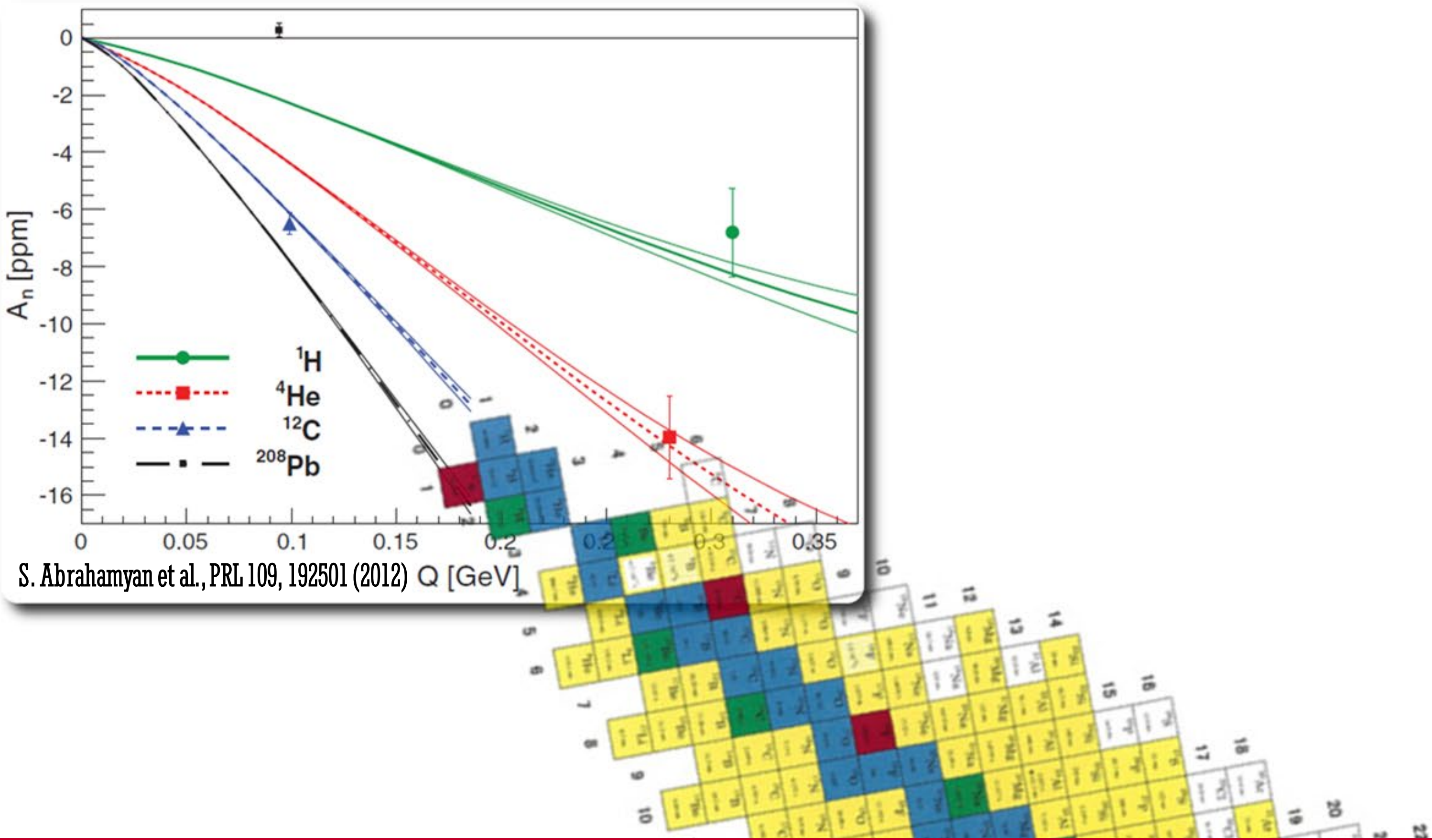


exact calculation … room for improvements



S. Abrahamyan et al., PRL 109, 192501 (2012)

the whole nuclear chart in a small band



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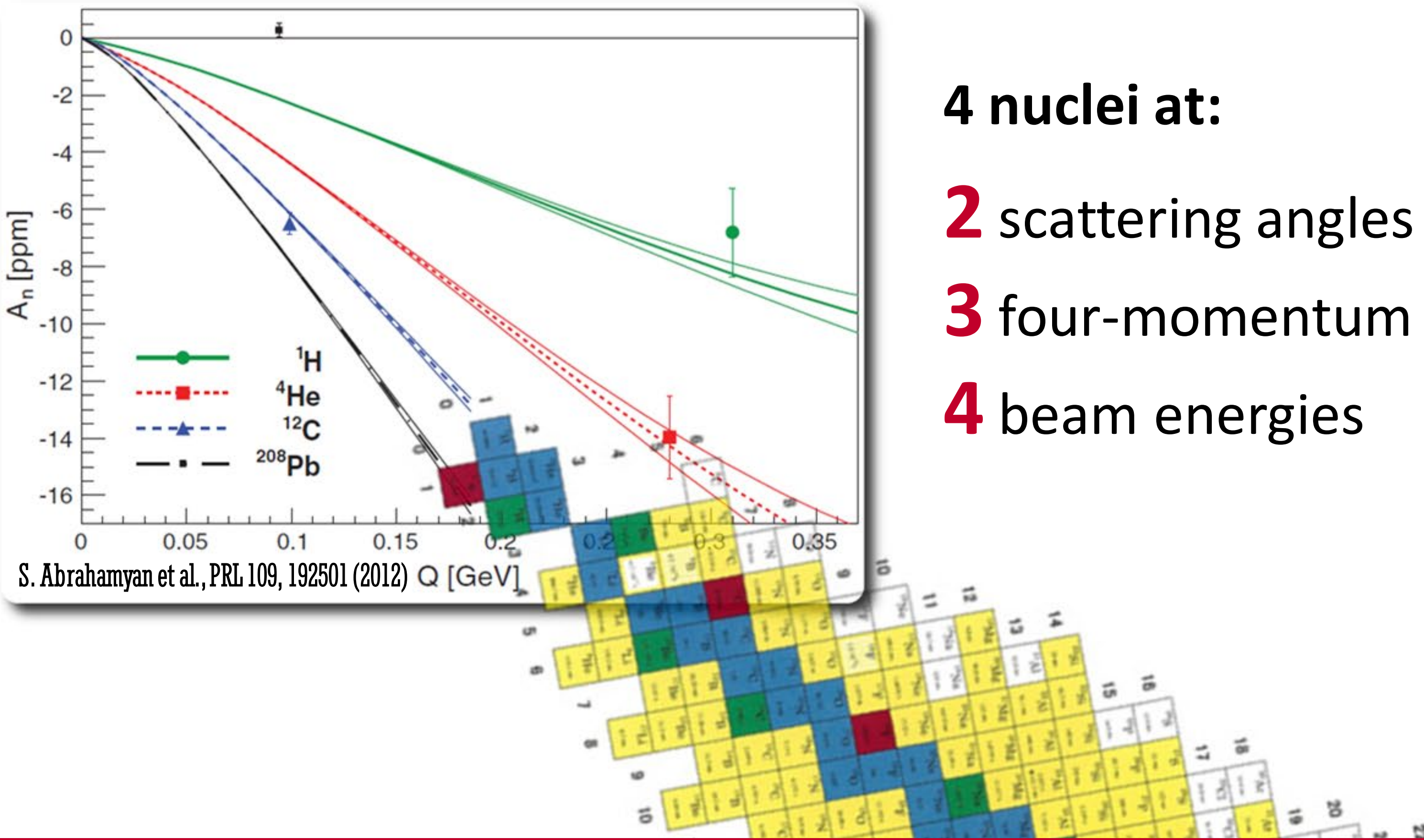


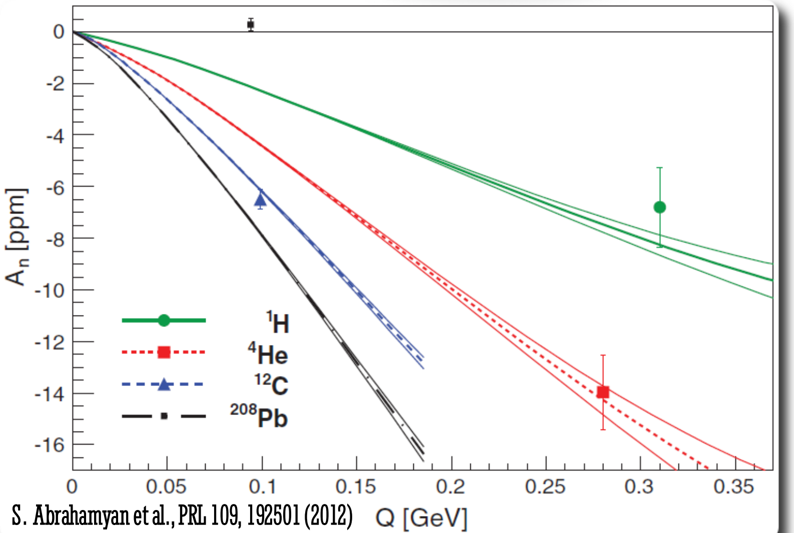
4 nuclei at:

2 scattering angles

3 four-momentum transfers

4 beam energies

compare apples with oranges?



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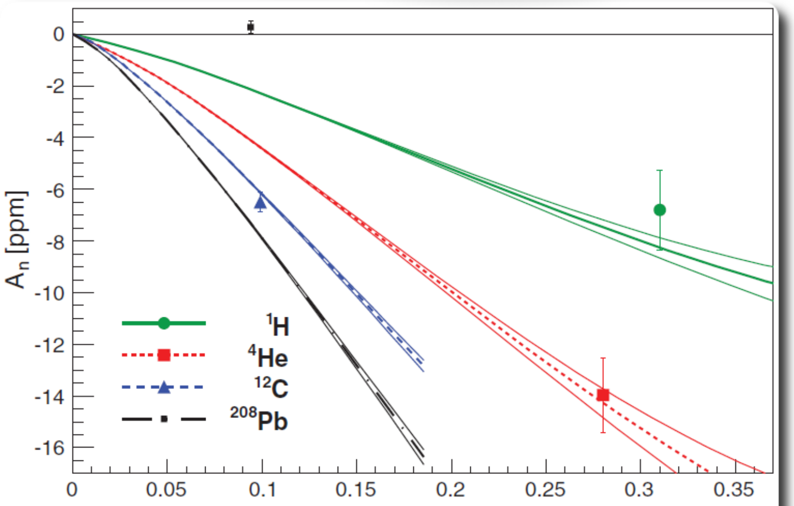


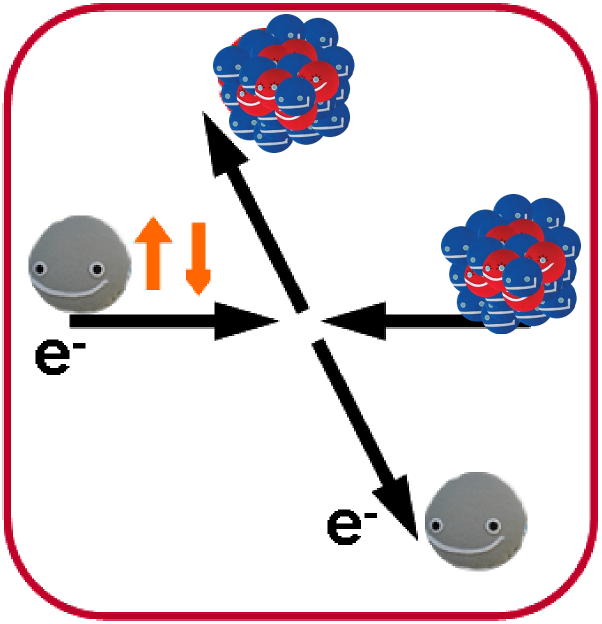
S. Abrahamyan et al., PRL 109, 192501 (2012)

disentangle

Q^2, E and A dependencies!

experimental access to A_n

elastic electron-nucleus scattering



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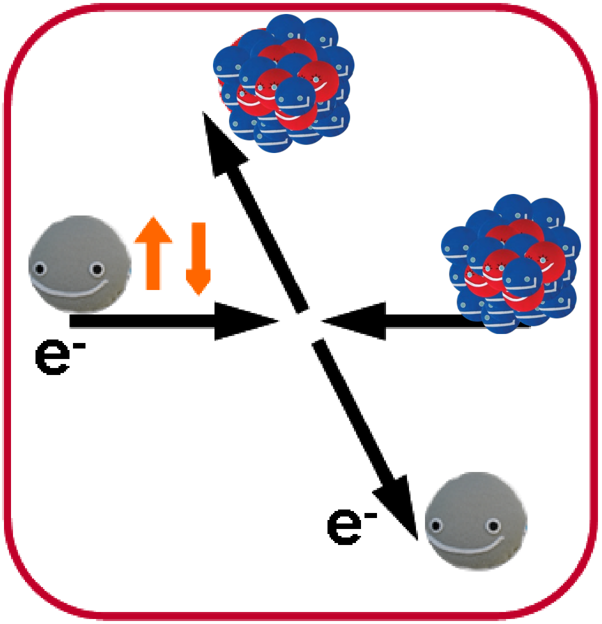

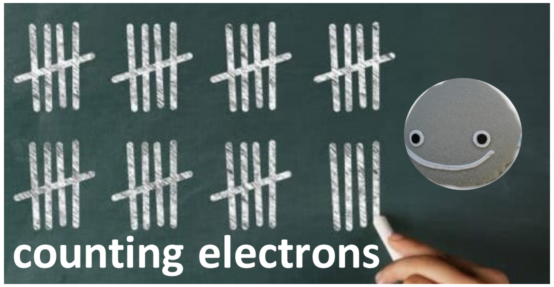

experimental access to A_n

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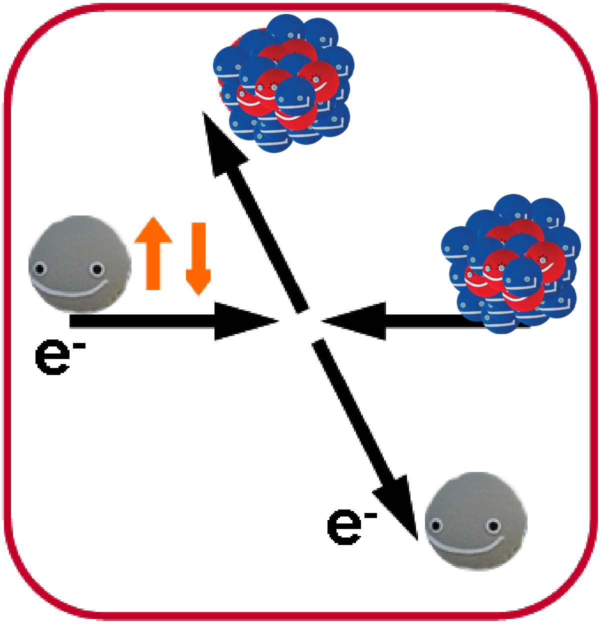
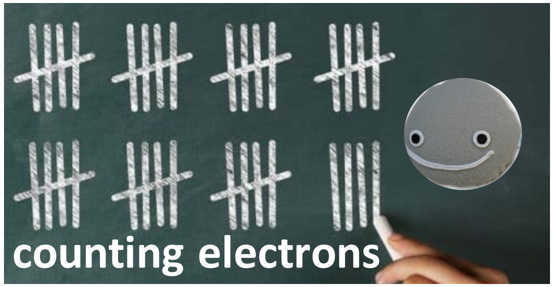


$$A_n = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} \approx 10^{-6} - 10^{-5}$$



experimental challenges

HIGH beam current

+ HIGH polarization

+ HIGH cross section

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reasonable long measuring time

experimental challenges

HIGH beam current

+ HIGH polarization

+ HIGH cross section

reasonable long measuring time

requirements:

outstanding beam (polarization & stability)

outstanding polarimetry

„right“ target material

low noise electronics

the stage

Mainz Microtron

up to E = 1.6 GeV

HIGH

resolution

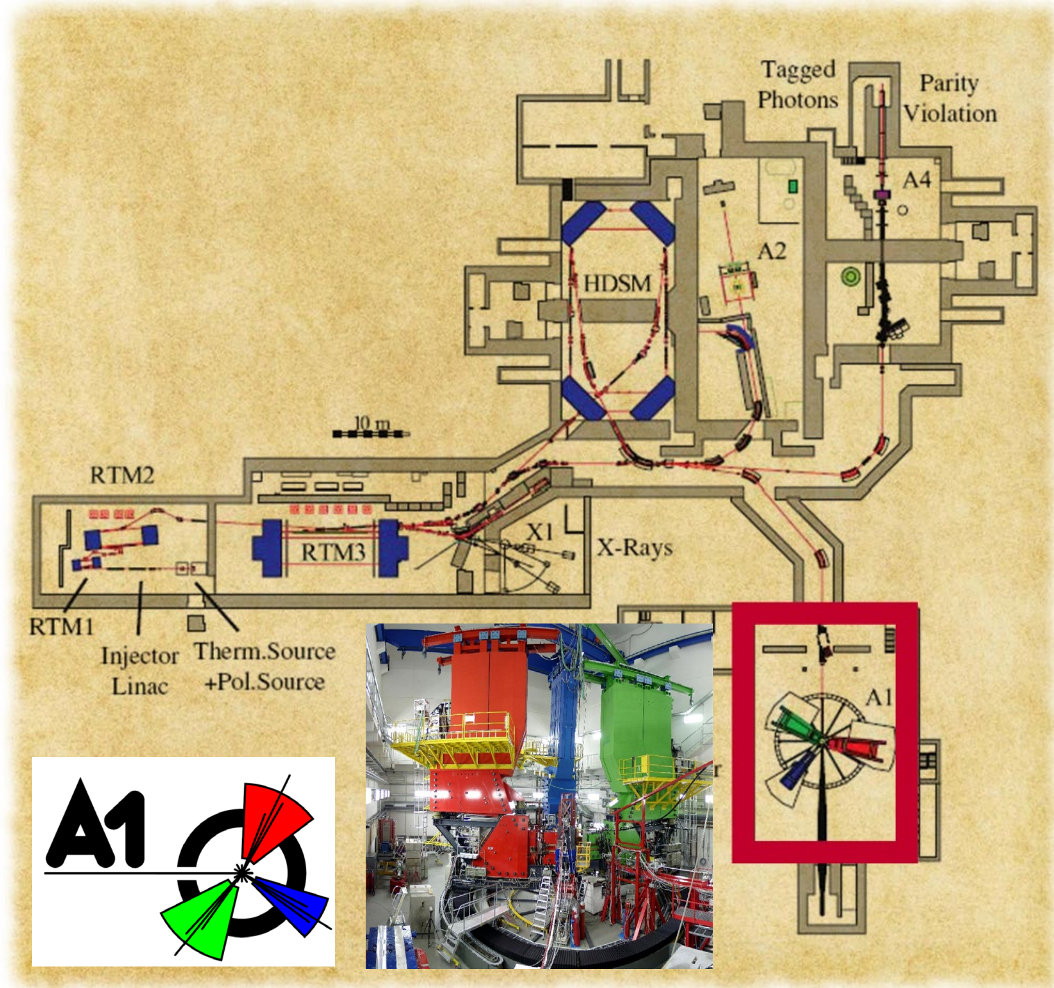
$\sigma_E < 0.1$ MeV

reliability

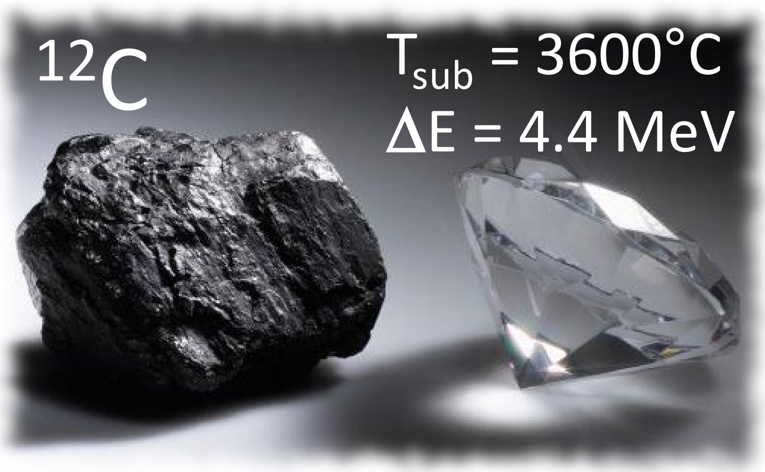
85% (7000 h/a)

polarization

up to 80% @ 40μA



the „right“ target material



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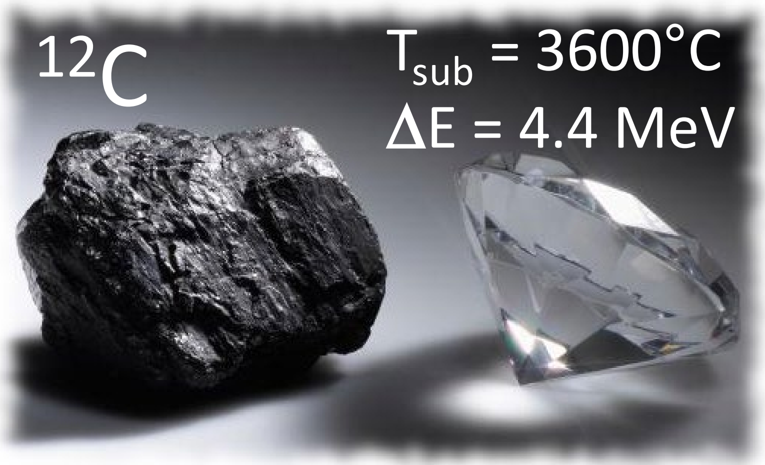
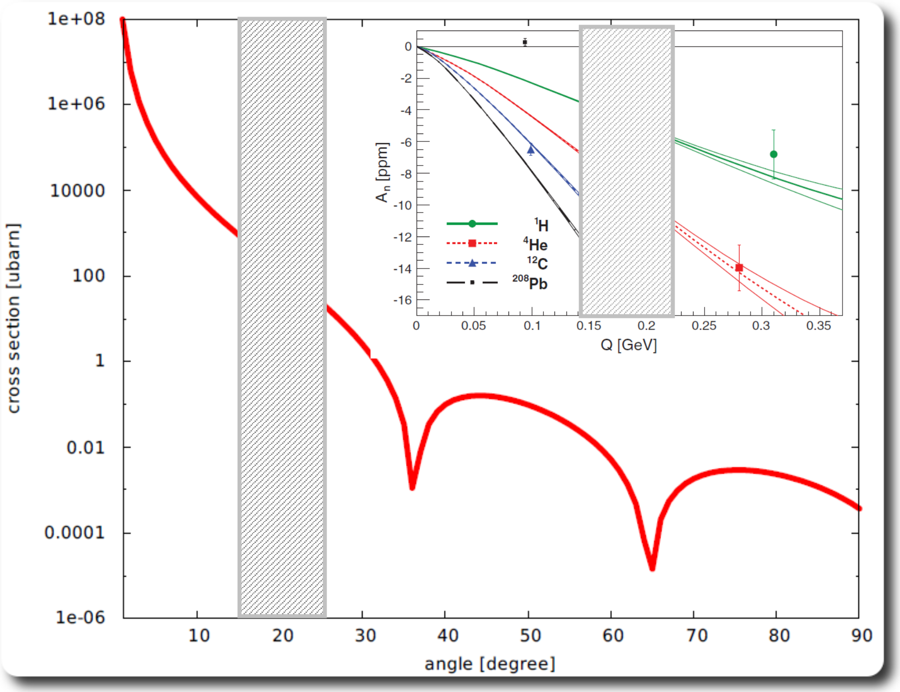


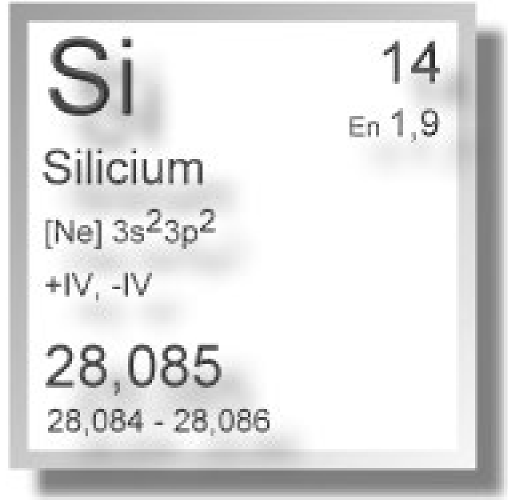
choice of kinematics



study Q^2 dependence

the „right“ target material

T_{sub} = 3600°C
ΔE = 4.4 MeV



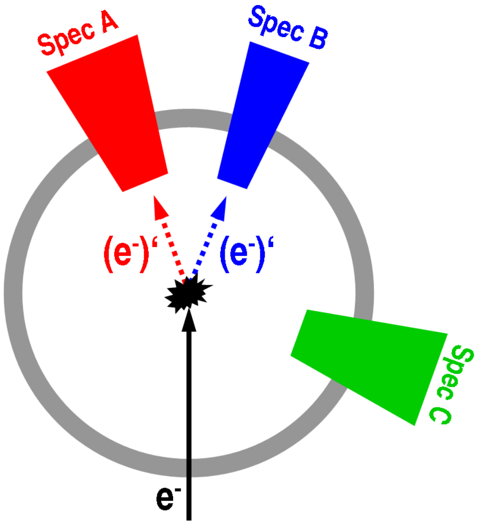
T_{melt} = 1410°C
ΔE = 1.8 MeV

T_{melt} = 1850°C
ΔE = 1.8 MeV

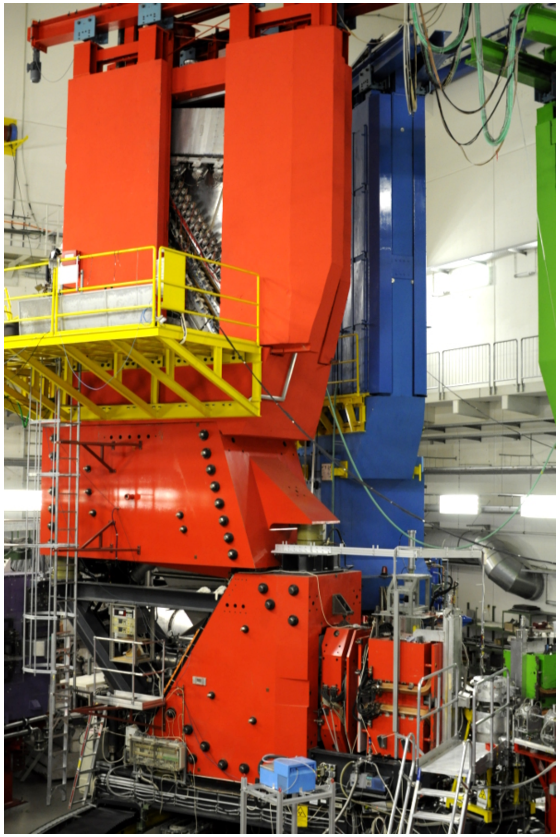
study A dependence

experimental setup

magnetic spectrometers

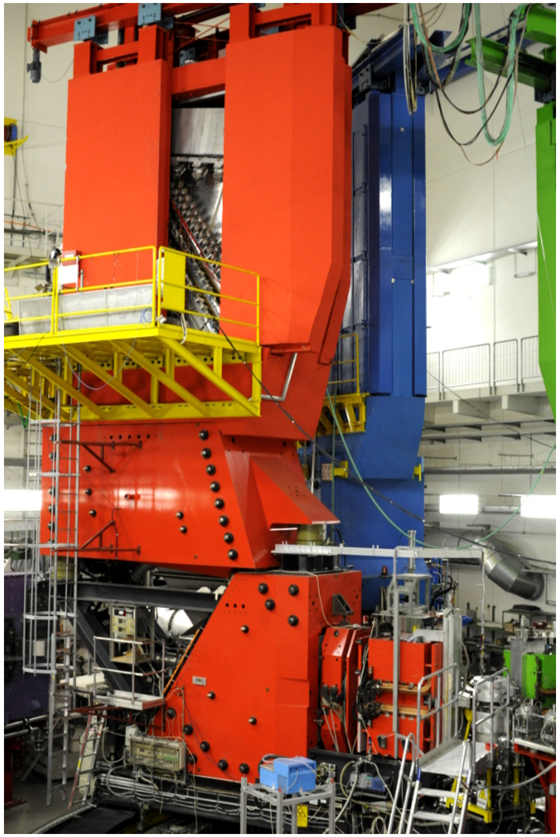


experimental setup
magnetic spectrometers

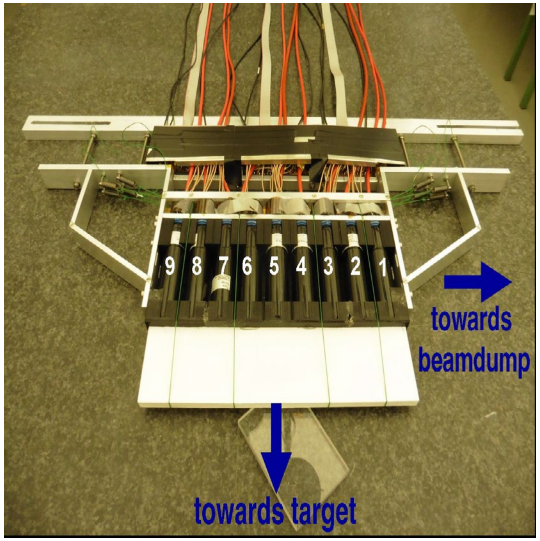


experimental setup

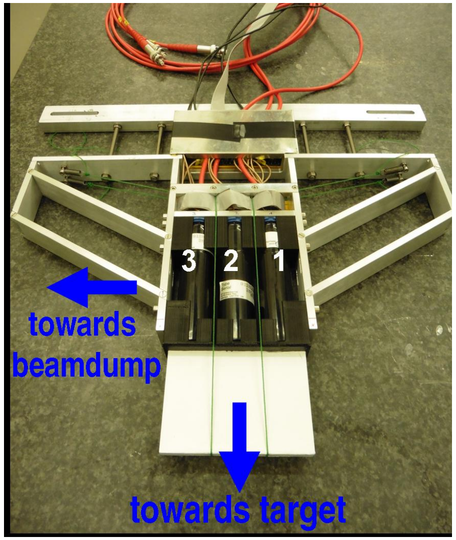
magnetic spectrometers



$A_n$det A

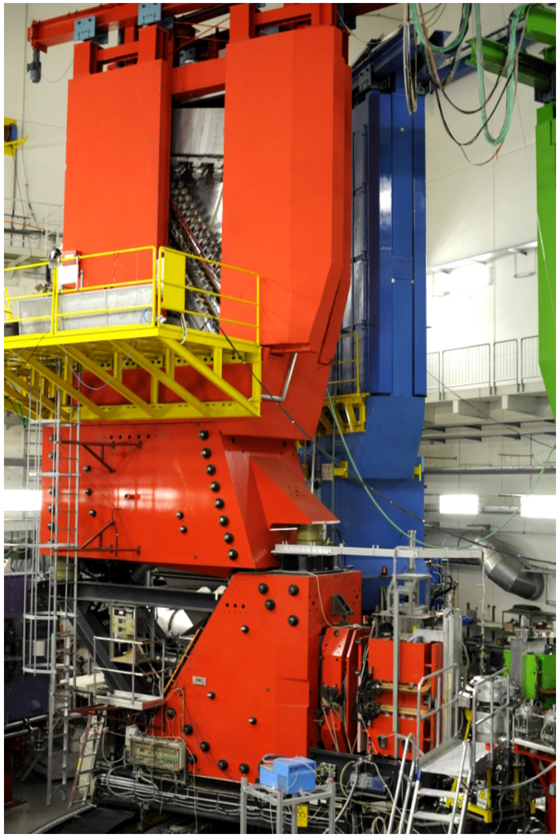


$A_n$det B

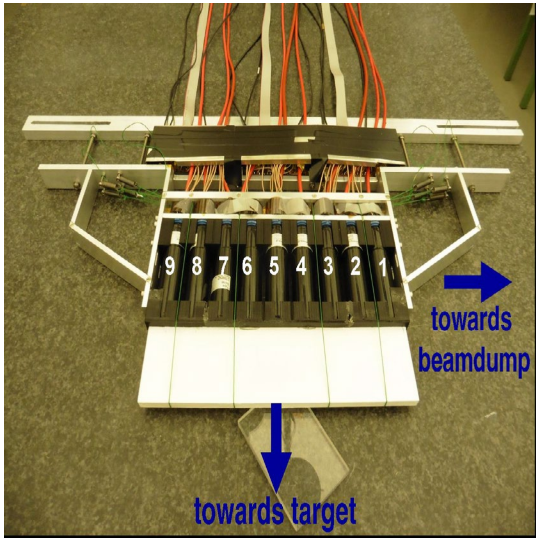


experimental setup

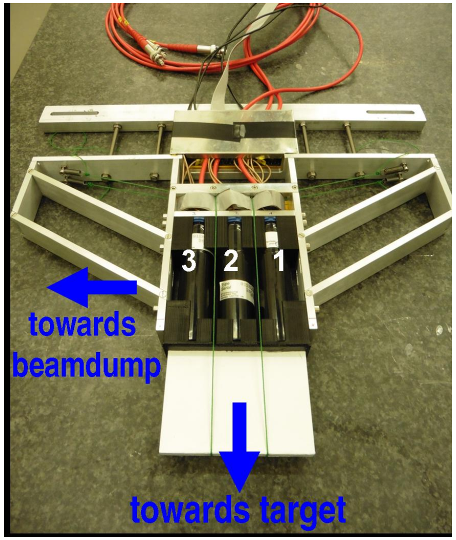
magnetic spectrometers

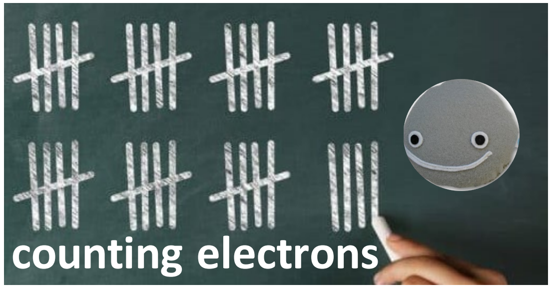


$A_n$det A



$A_n$det B





false asymmetries

beam related sources:

current

energy

position and angle

non-beam related sources:

ground noise

gate length fluctuations

electrical cross talk

false asymmetries

beam related sources:

current

energy

position and angle

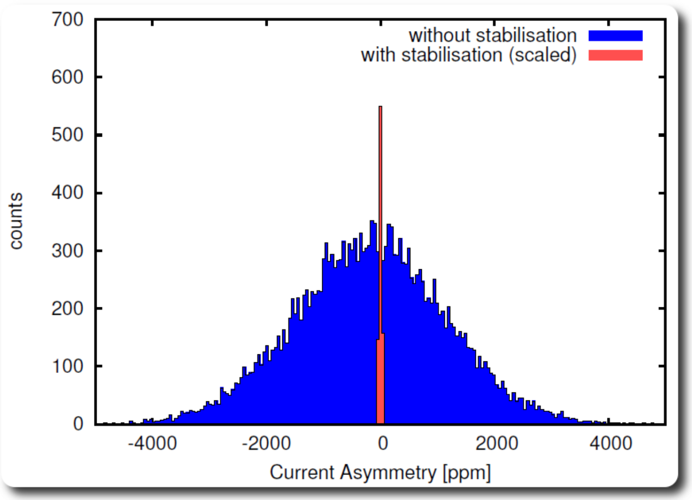
non-beam related sources:

ground noise

gate length fluctuations

electrical cross talk

stabilization system needed!



hardware suppression:

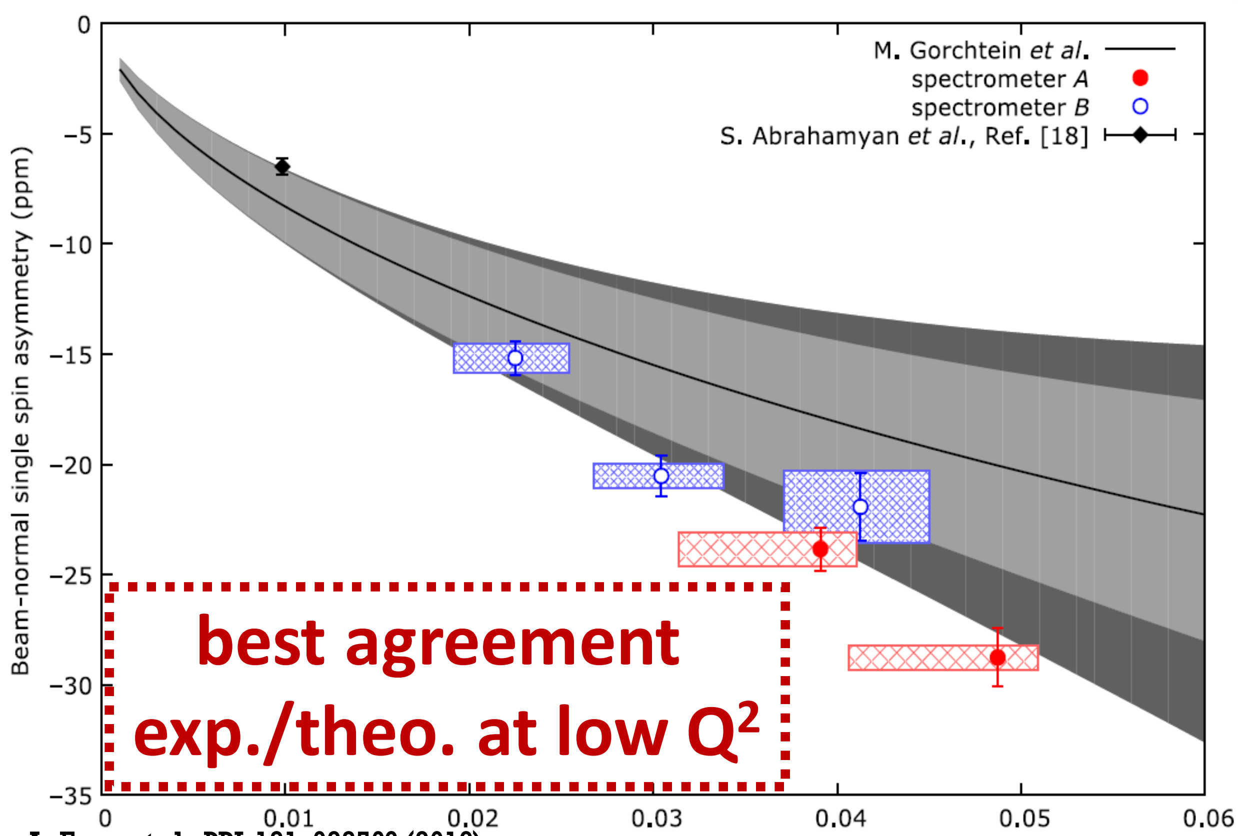
⊗ ⊙ ⊙ ⊗   ⊙ ⊗ ⊗ ⊙

synchronization with power grid

random polarity sequence

inversion of general sign

results - Q^2 dependence



A. Esser et al., PRL 121, 022503 (2018)

^{12}C:

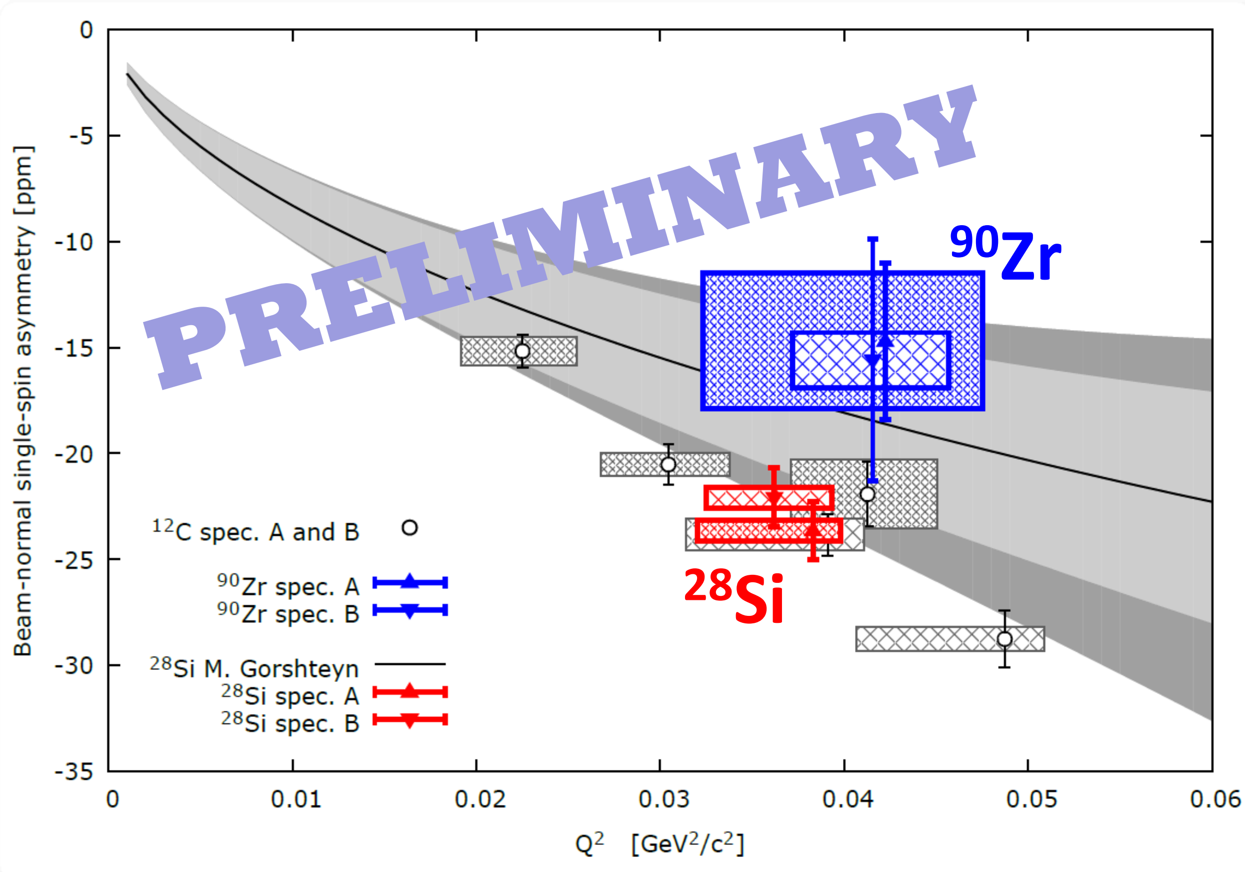
$0.02\ GeV^2 \leq Q^2 \leq 0.05\ GeV^2$

uncertainty of
Compton slope parameter:

± 10%

± 20%

results - A dependence



^{12}C, ^{28}Si, ^{90}Zr:

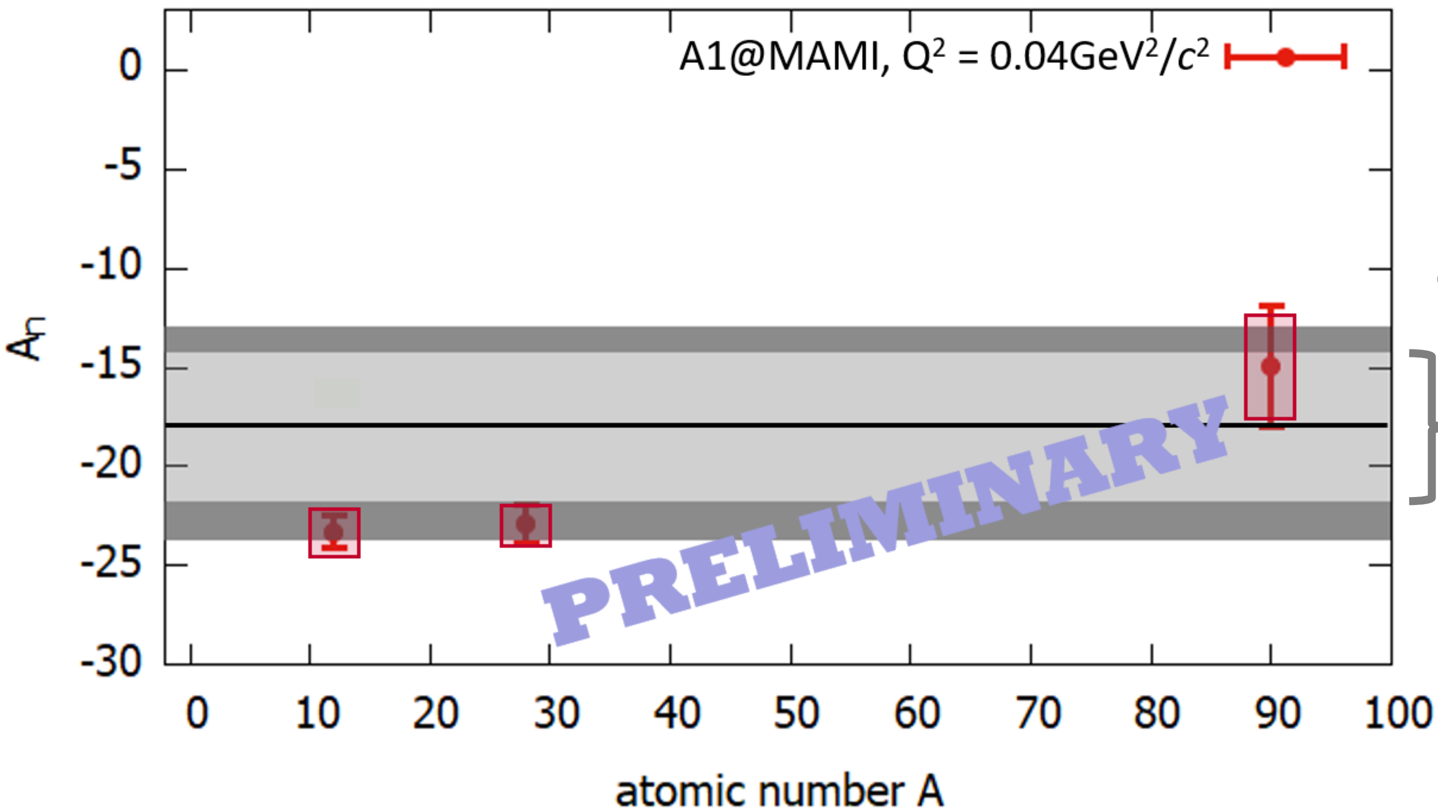
$Q^2 = 0.04\ GeV^2$

uncertainty of Compton slope parameter:

± 10%

± 20%

results - A dependence

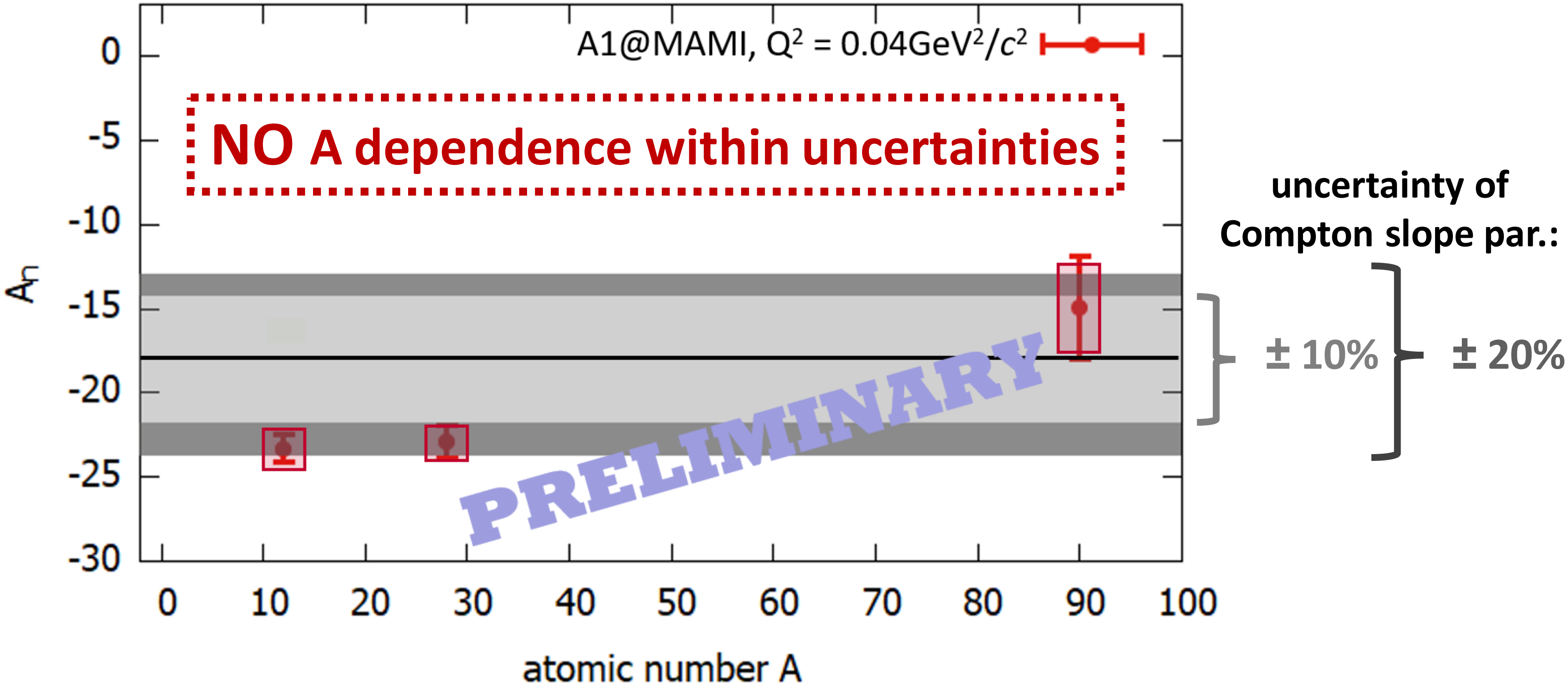


uncertainty of Compton slope par.:

± 10%

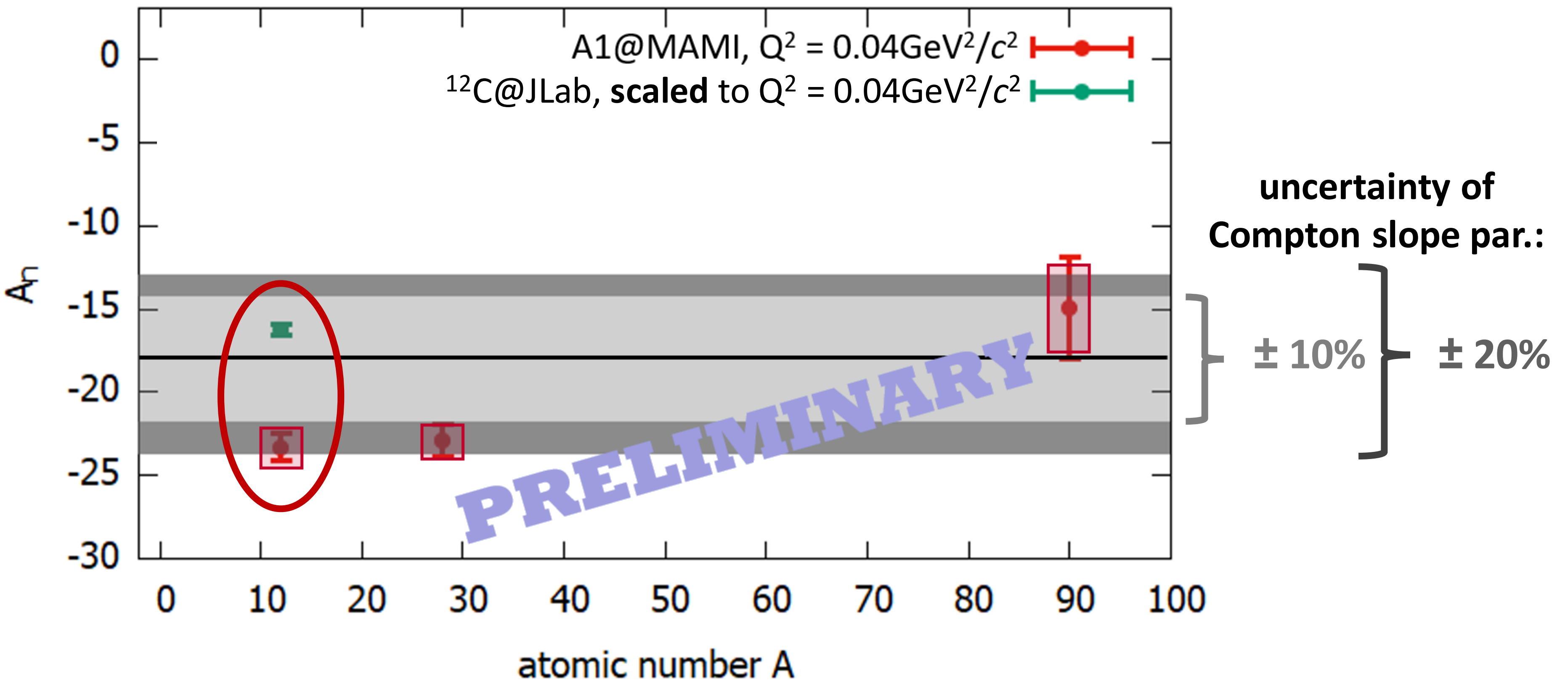
± 20%

results - A dependence



uncertainty of
Compton slope par.:

what if … combining MAMI and Jlab results?



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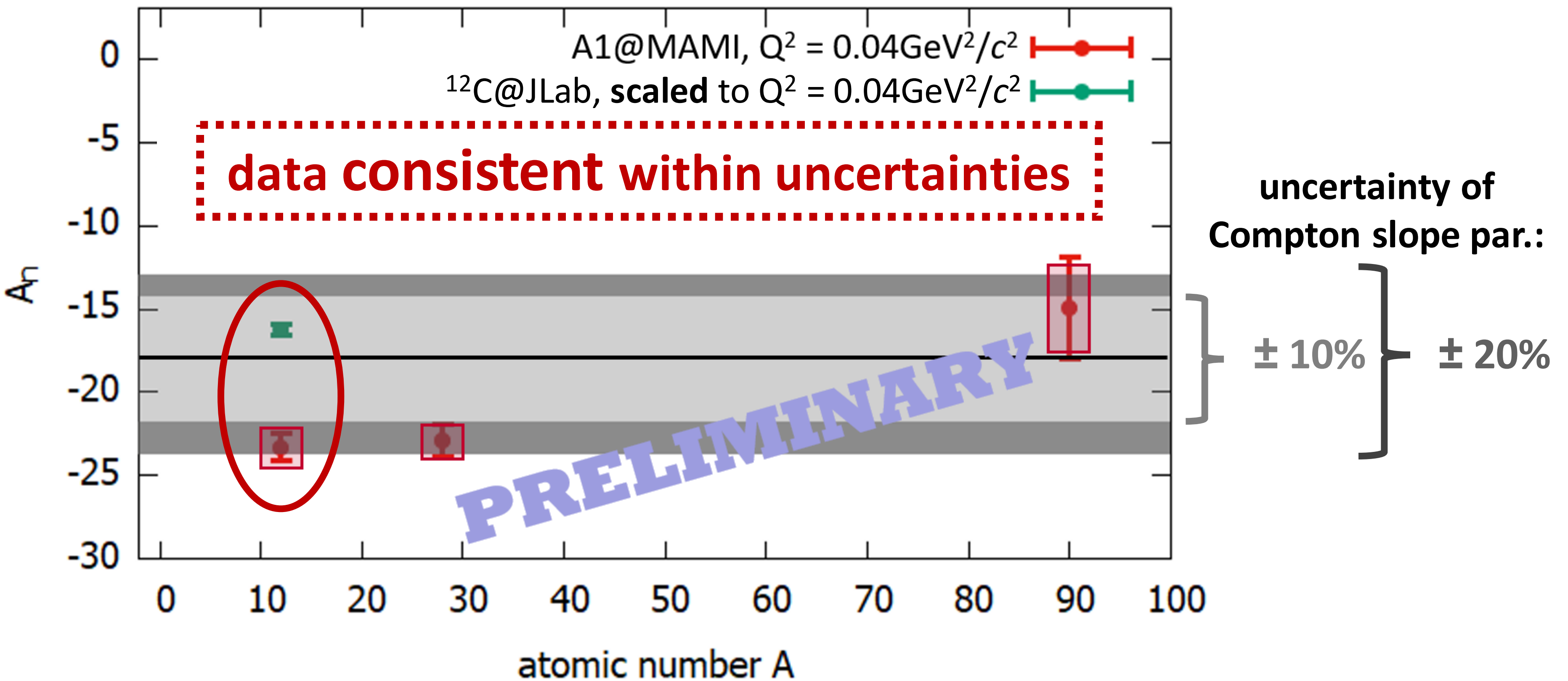

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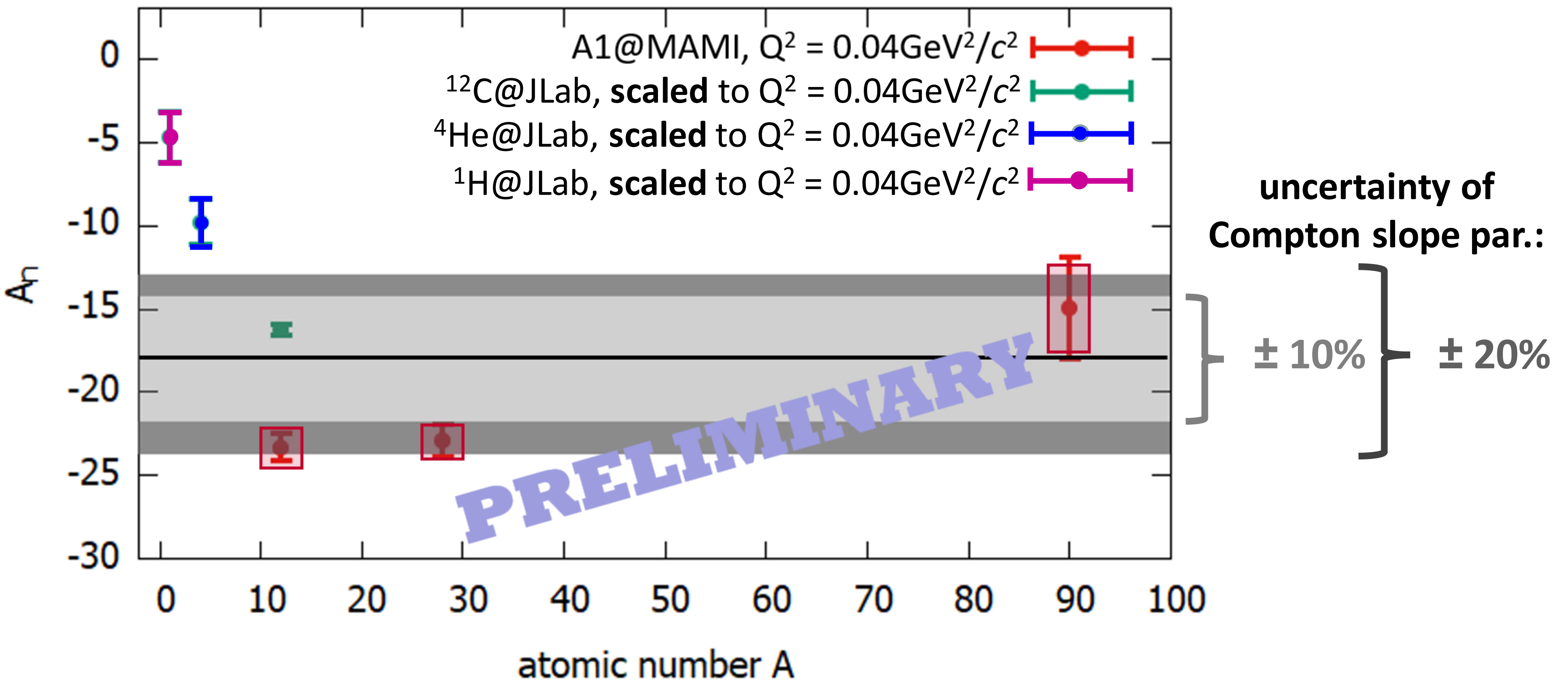

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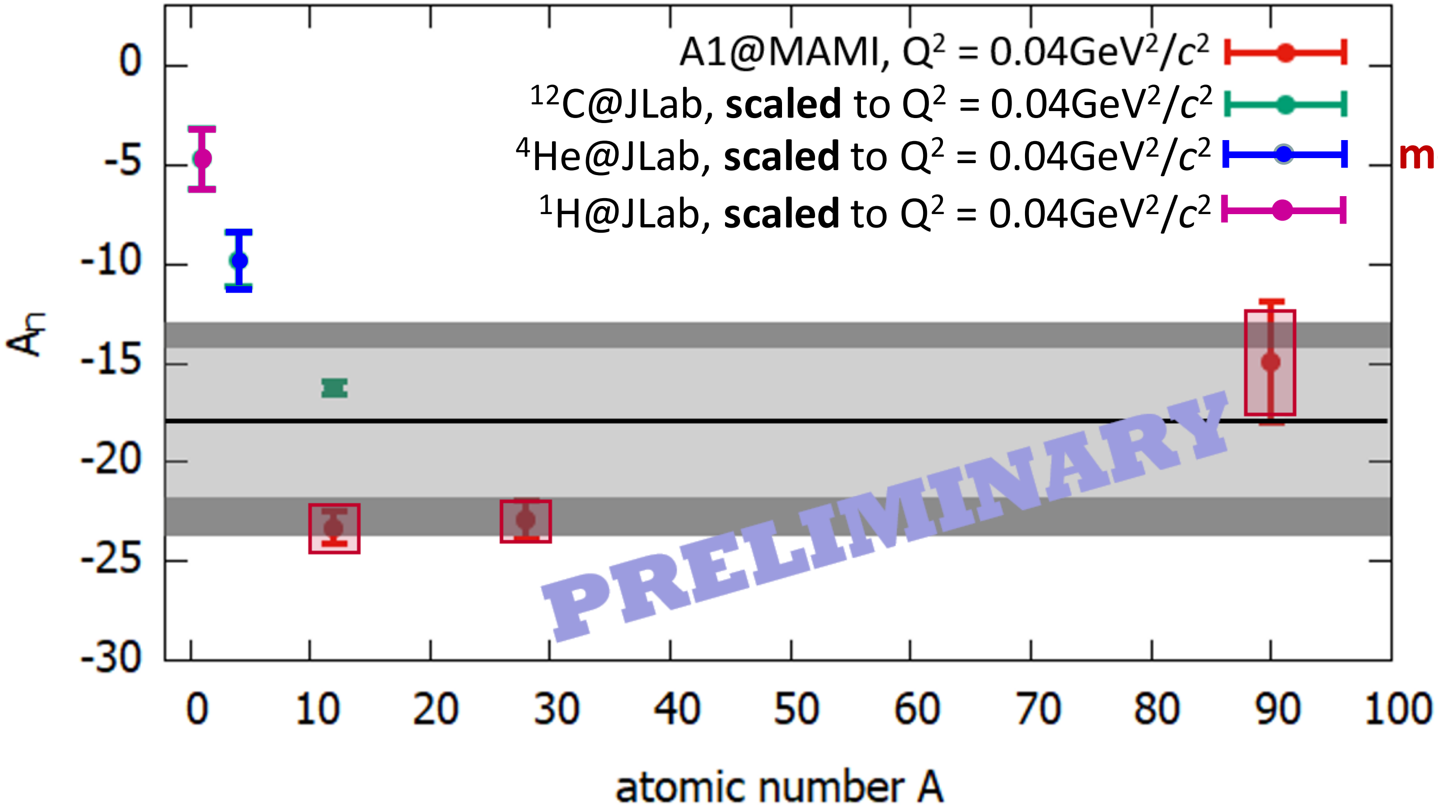
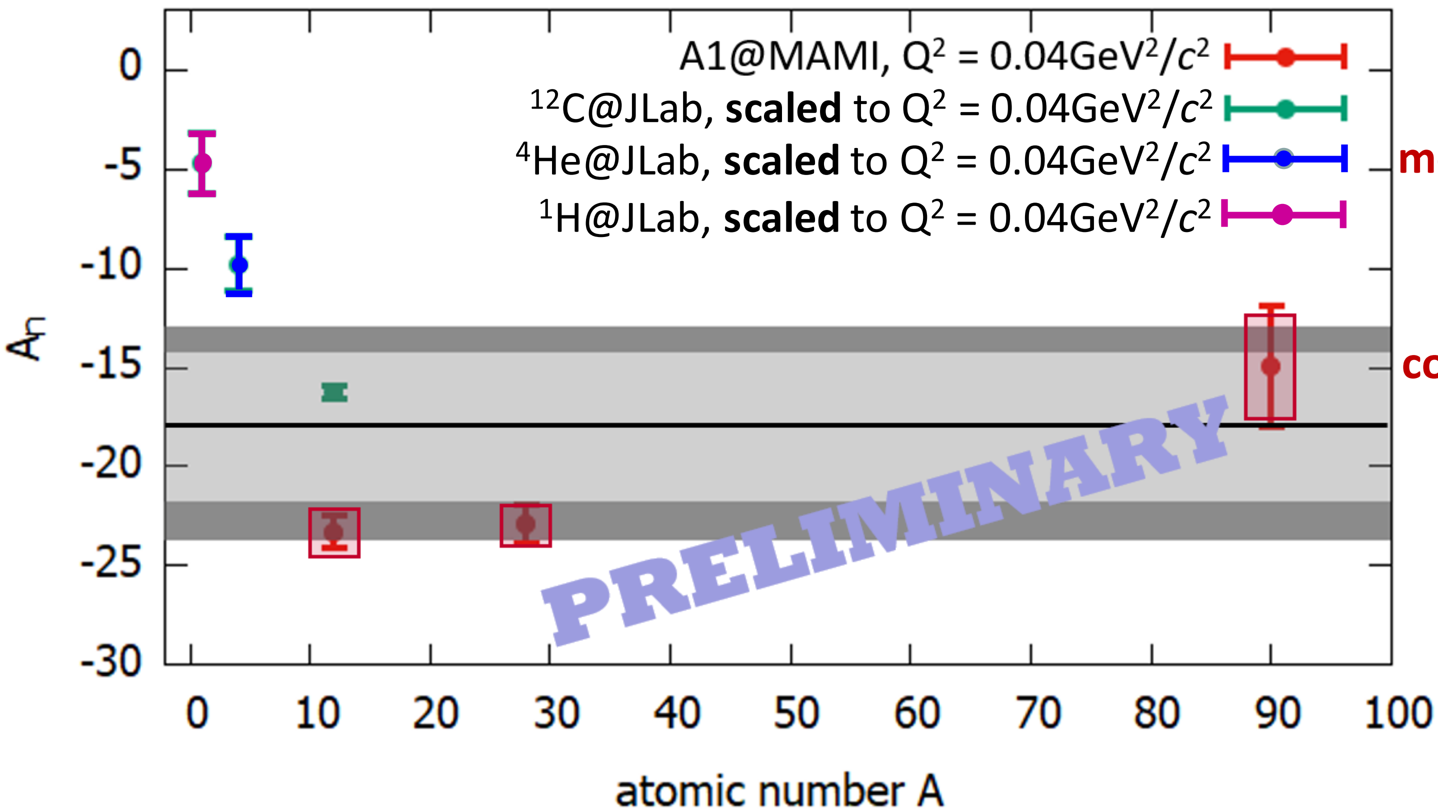


Compton slope par.
measured for ¹H and ⁴He

what if … combining MAMI and Jlab results?

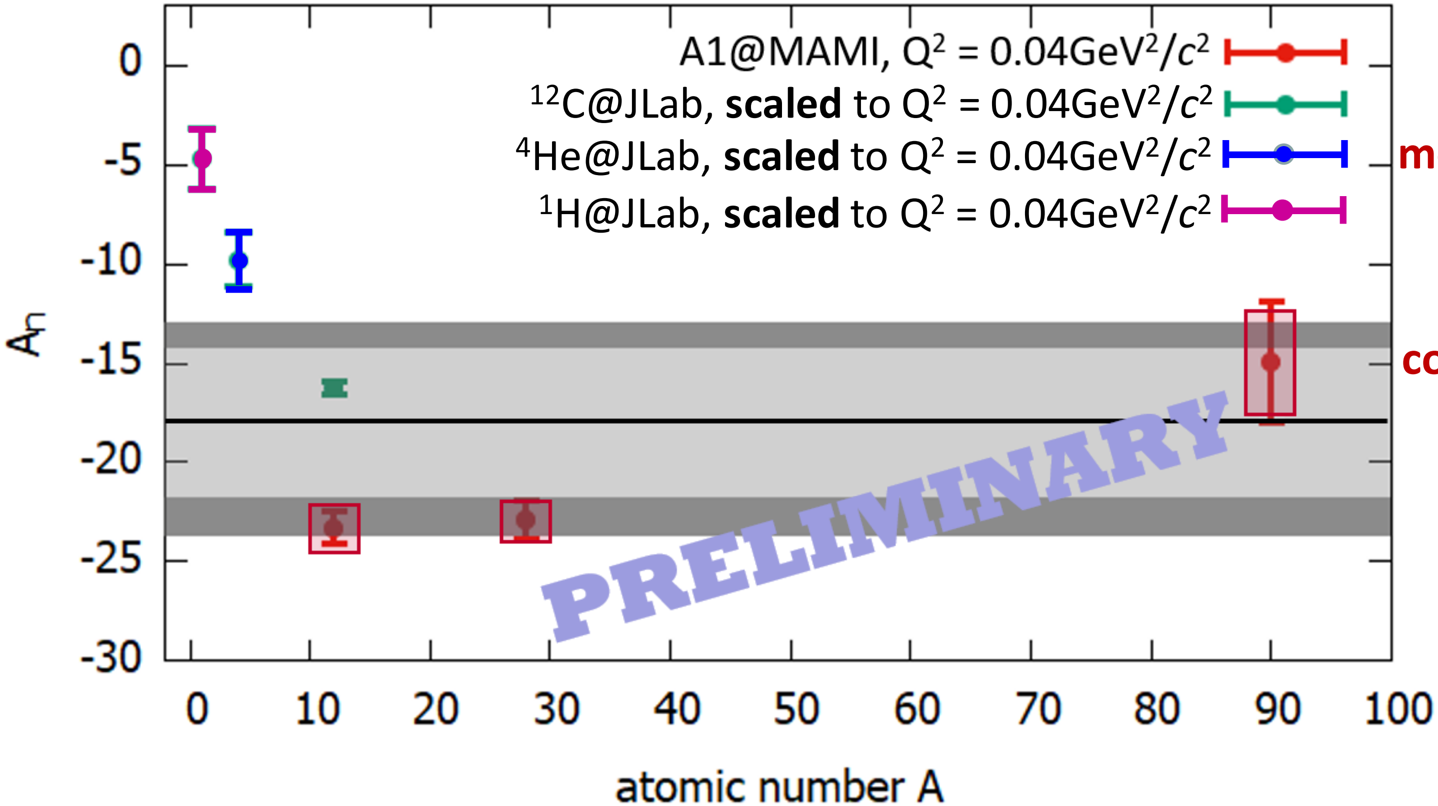


Compton slope par.
measured for ^1H and ^4He

+

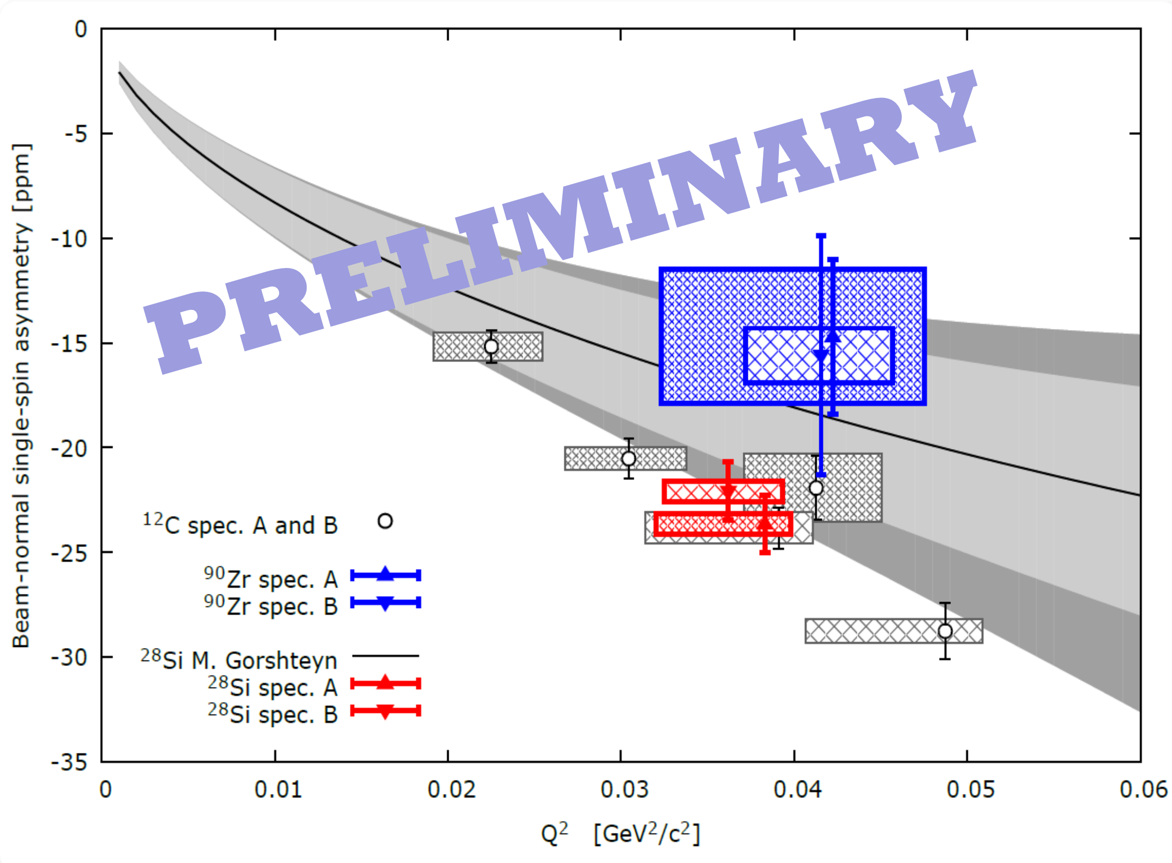
energy dependence
considered in theo. calc.

what if … combining MAMI and Jlab results?



Compton slope par.
measured for ^{1}H and ^{4}He
+
energy dependence
considered in theo. calc.
=

conclusions



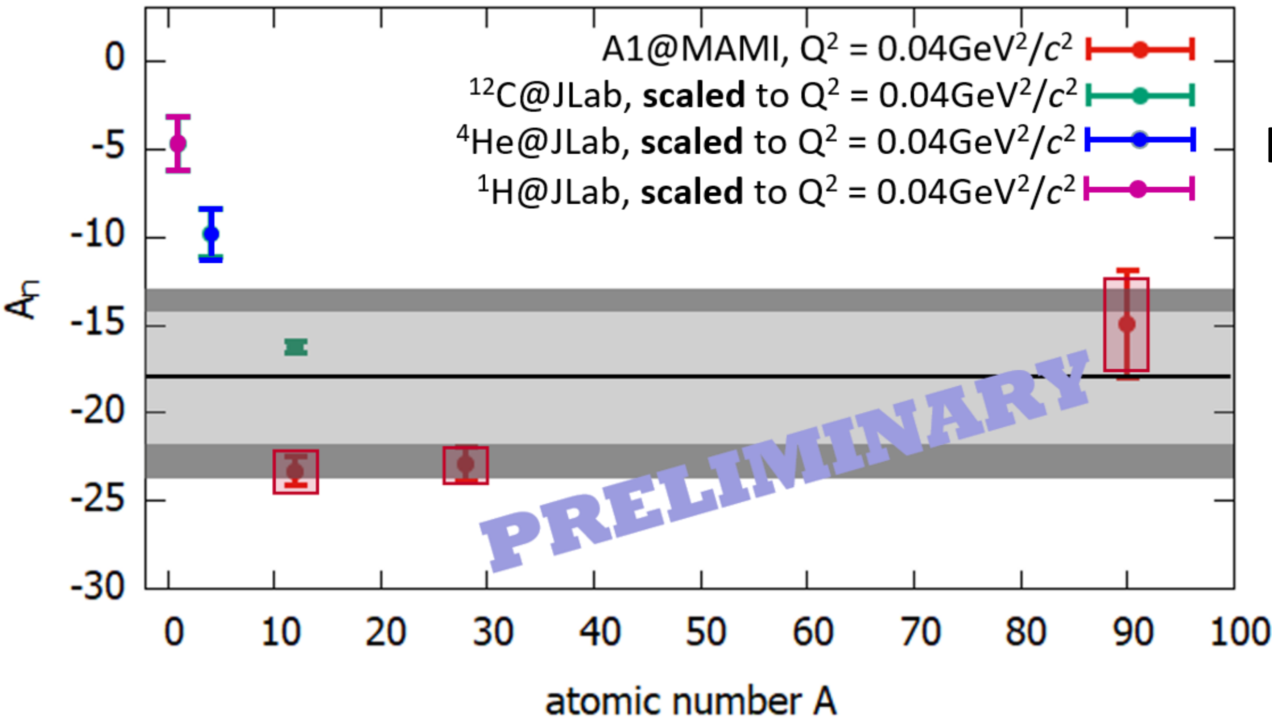
Q^2 - dependence (^{12}C) ✓

no A - dependence (^{12}C, ^{28}Si, ^{90}Zr) ✓

„PHYSICS IS REALLY NOTHING MORE THAN A SEARCH FOR ULTIMATE SIMPLICITY, BUT SO FAR ALL WE HAVE IS A KIND OF ELEGANT MESSINESS.“

BILL BRYSON, A SHORT HISTORY OF NEARLY EVERYTHING

conclusions



Q^2 - dependence (^{12}C) ✓

no A - dependence (^{12}C, ^{28}Si, ^{90}Zr) ✓

exp. vs theo. ✗

„Physics is really nothing more than a search for ultimate simplicity, but so far all we have is a kind of elegant messiness.“

Bill Bryson, A Short History of Nearly Everything

next steps

measure

energy dependence

(^{12}C)

measure

Compton Slope

($\geq$ ^{12}C)

„Physics is really nothing more than a search for ultimate simplicity, but so far all we have is a kind of elegant messiness.“

Bill Bryson, A Short History of Nearly Everything

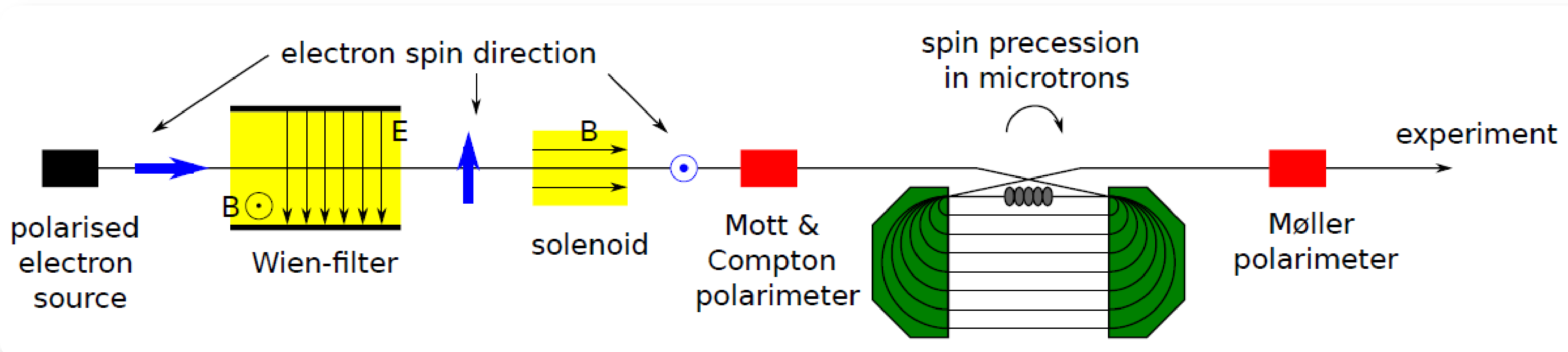
polarimetry measure v[illegible]nsverse polarization

ACCESS DENIED

THE TOOLS:

Mott: horizontal transverse @ source

Møller: longitudinal @ target



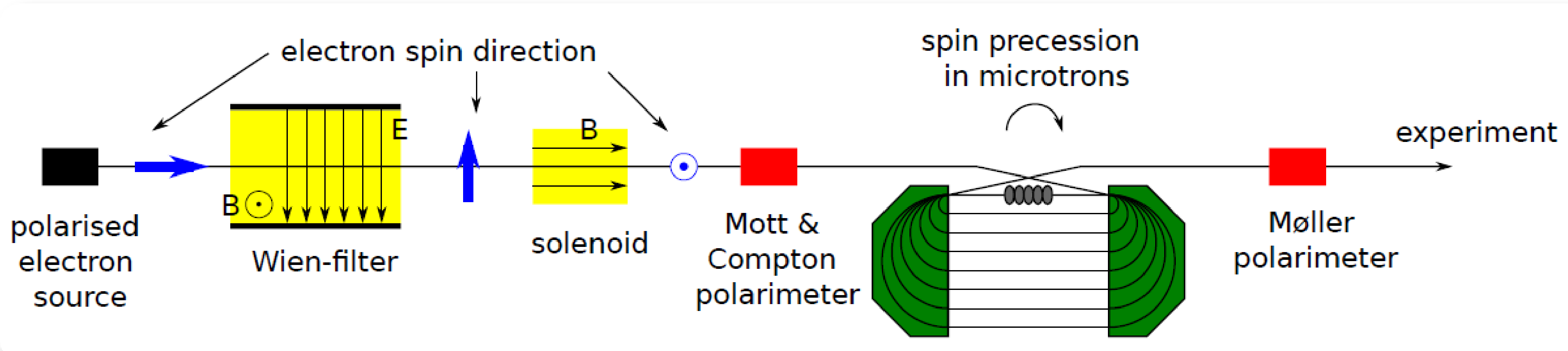
polarimetry measure vertical transverse polarization

THE METHOD:

MAXIMIZE longitudinal polarization @ target

MAXIMIZE horizontal transverse component @ source

MINIMIZE longitudinal and transverse component @ source and target



For details see: B.S. Schlimme et al., NIM A 850 (2017) 54-60