180° Electron Scattering at the S-DALINAC

Peter von Neumann-Cosel
Institut für Kernphysik, Technische Universität Darmstadt

- The S-DALINAC
- Transverse response with a 180° scattering system
- Examples of neutrino-related research
  - neutral current reactions in supernovae
  - quenching of spin-isospin matrix elements
- Future plans

Inelastic Electron Scattering

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- Form factors

$$\left(\frac{d\sigma}{d\omega}\right) = \left(\frac{d\sigma}{d\omega}\right)_L + \left(\frac{d\sigma}{d\omega}\right)_T$$

$$\left(\frac{d\sigma}{d\omega}\right)_L \propto V_L \times |F_L(\vec{q})|^2 \qquad \left(\frac{d\sigma}{d\omega}\right)_T \propto V_T \times |F_T(\vec{q})|^2$$

- momentum transfer dependence → crucial test of models
- spin-isospin response → F_T

- Experiments
  - S-DALINAC: only accelerator world-wide focused on nuclear structure
  - transverse part can be enhanced → 180° scattering
  - close relation between (e,e’) and (ν,ν‘) cross sections

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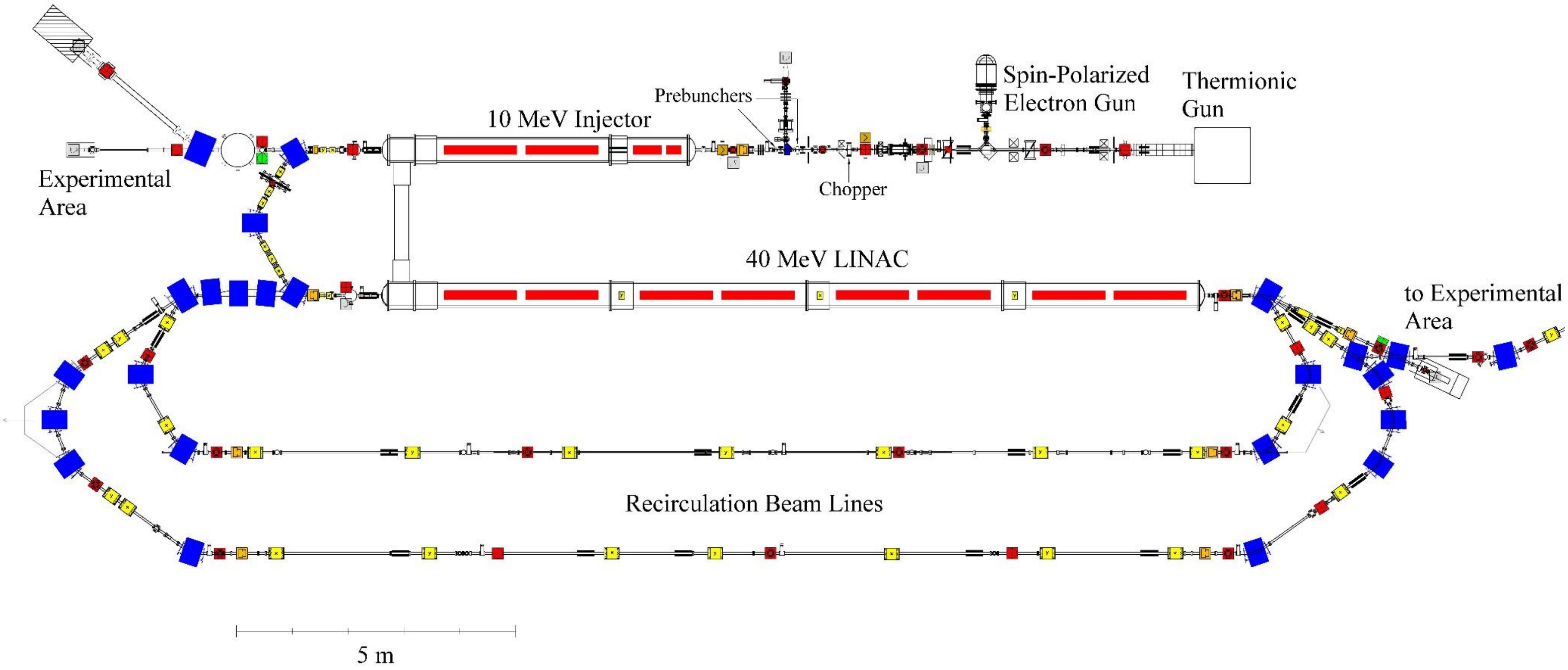
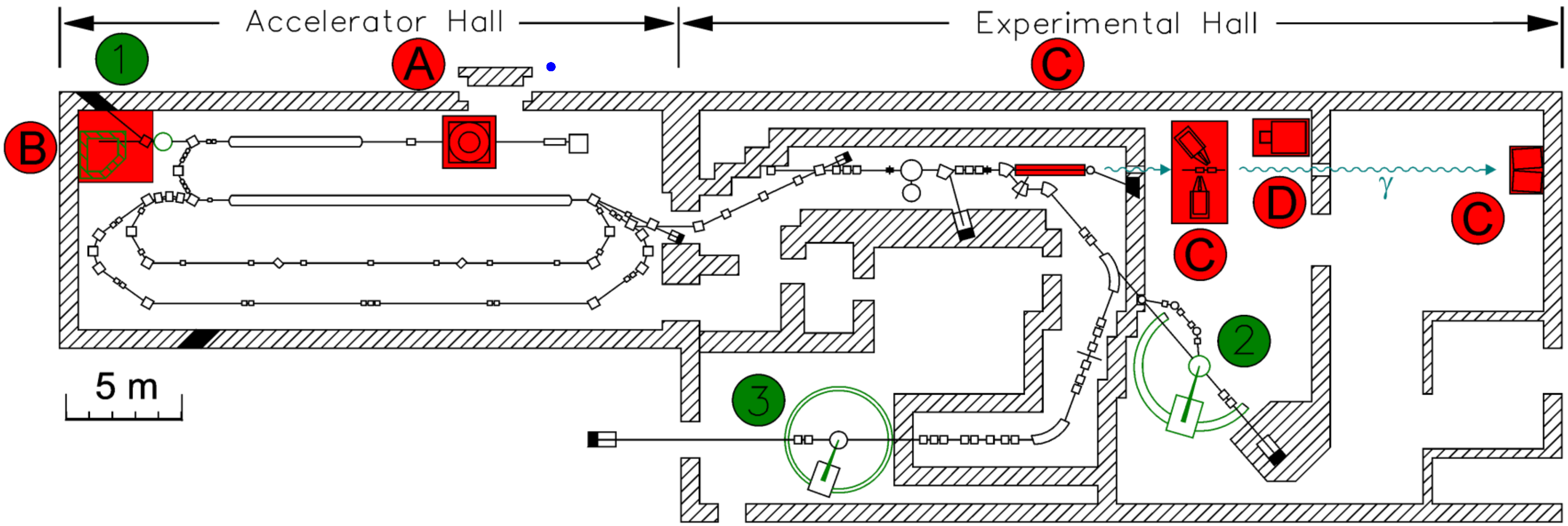
The S-DALINAC

S-DALINAC



presently E_{max} ≈ 80 MeV

Experiments at the S-DALINAC



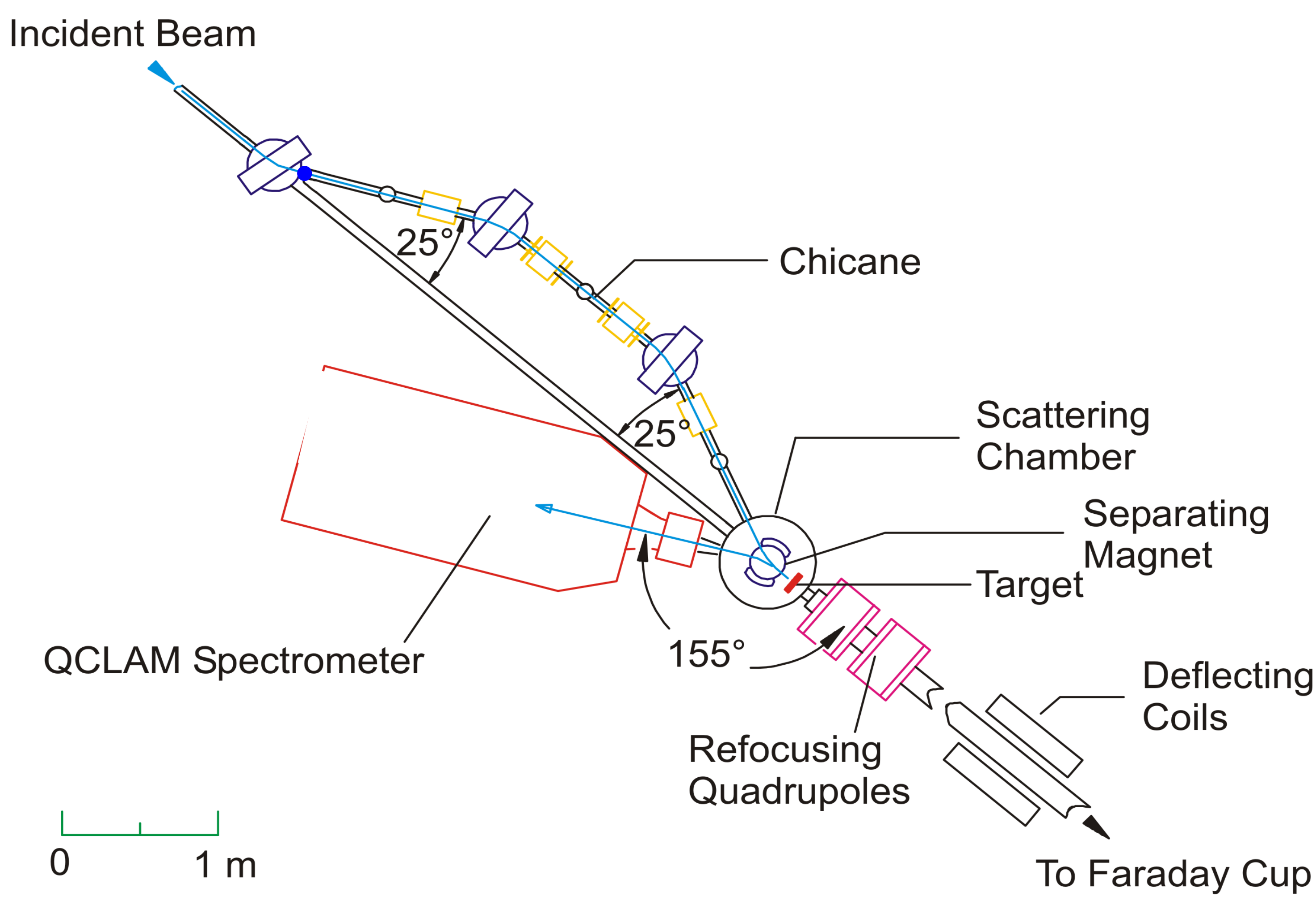
Status

1. Nuclear resonance fluorescence
2. (e,e´) and 180° experiments
3. High-resolution (e,e´) experiments

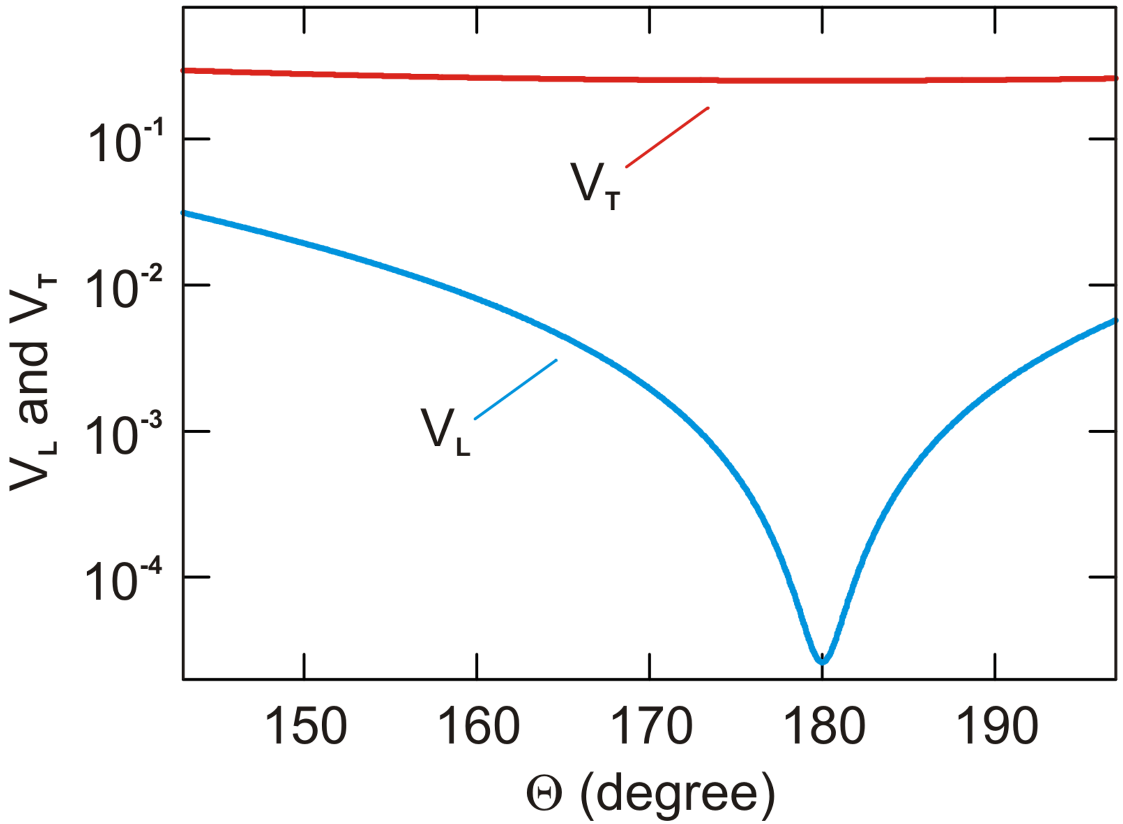
SFB

A. Polarized electron source
B. 14 MeV bremsstrahlung
C. 100 MeV bremsstrahlung for polarizability of the nucleon
D. Photon tagger

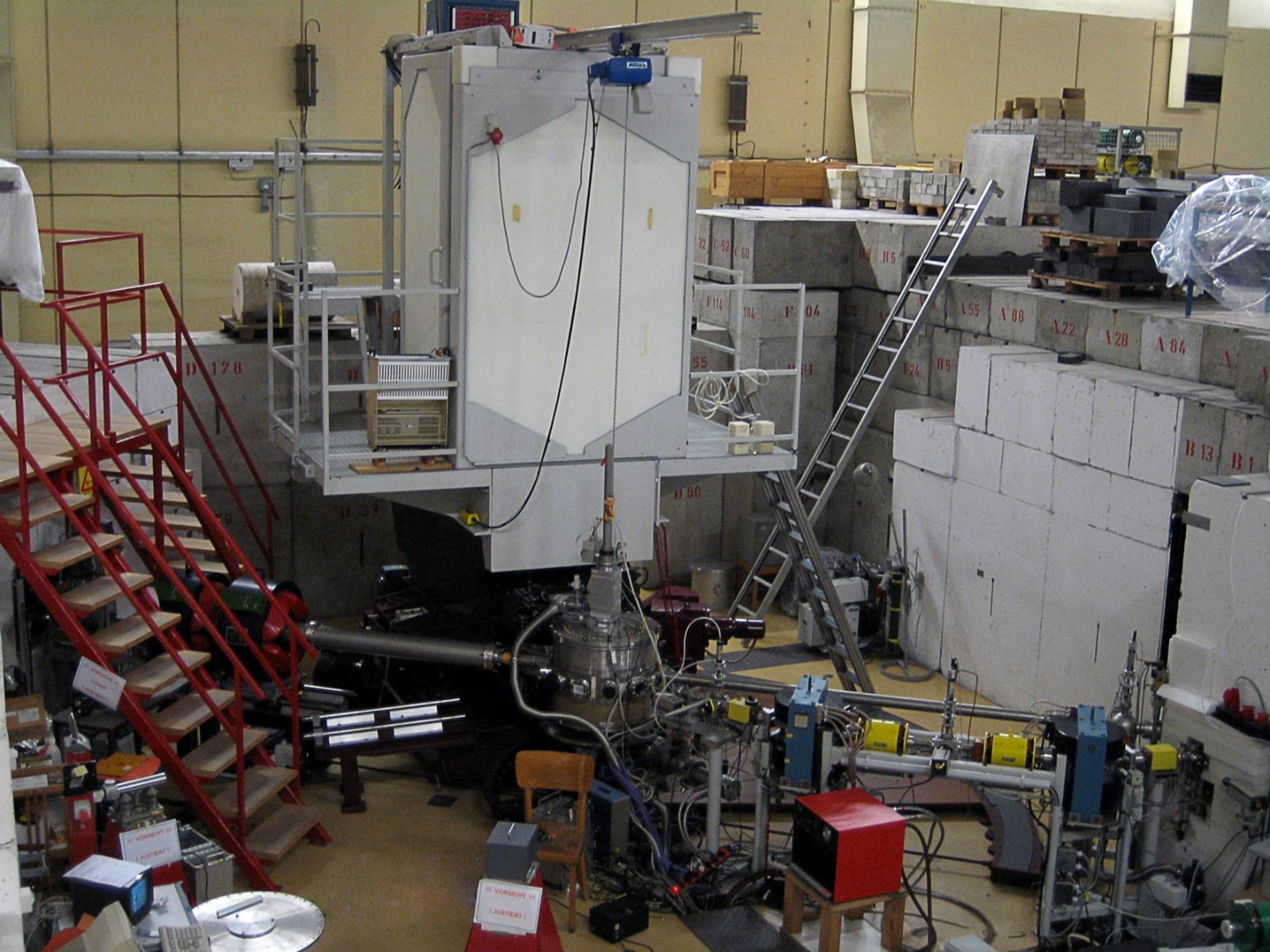
180° System at the S-DALINAC



Why 180° scattering?



Transverse response enhanced by 3 orders of magnitude!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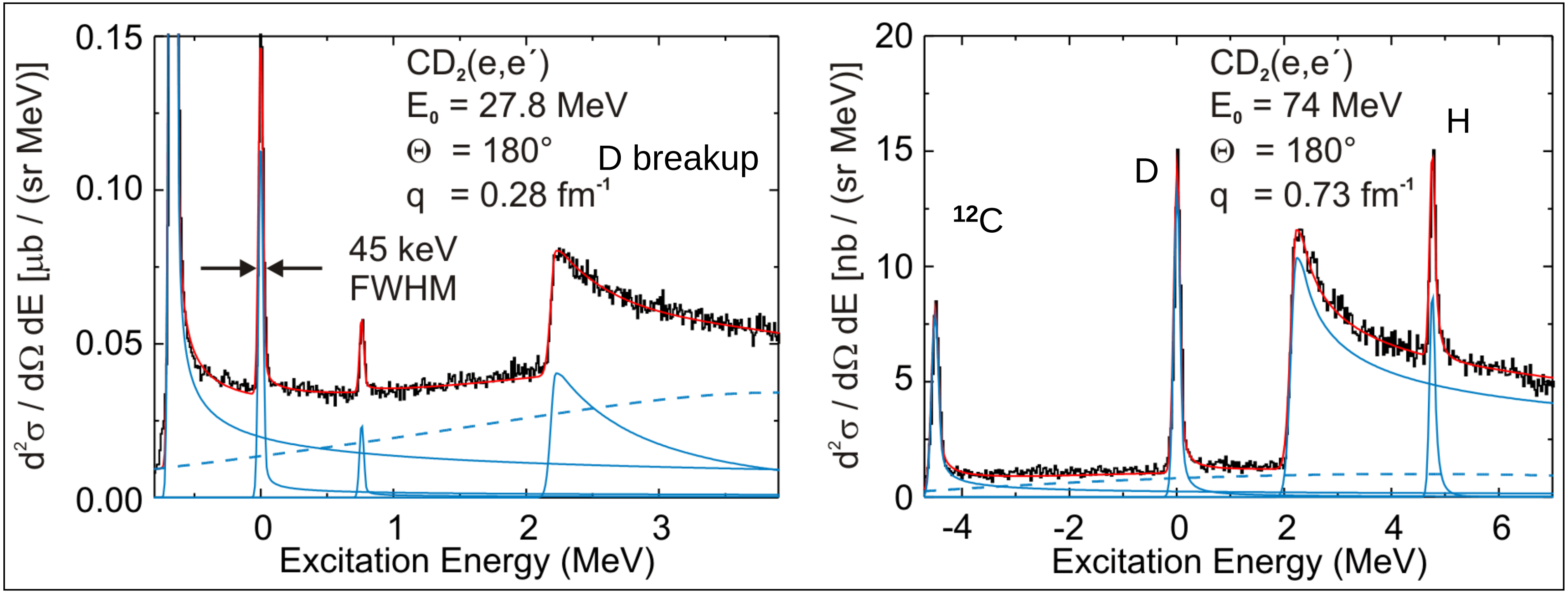
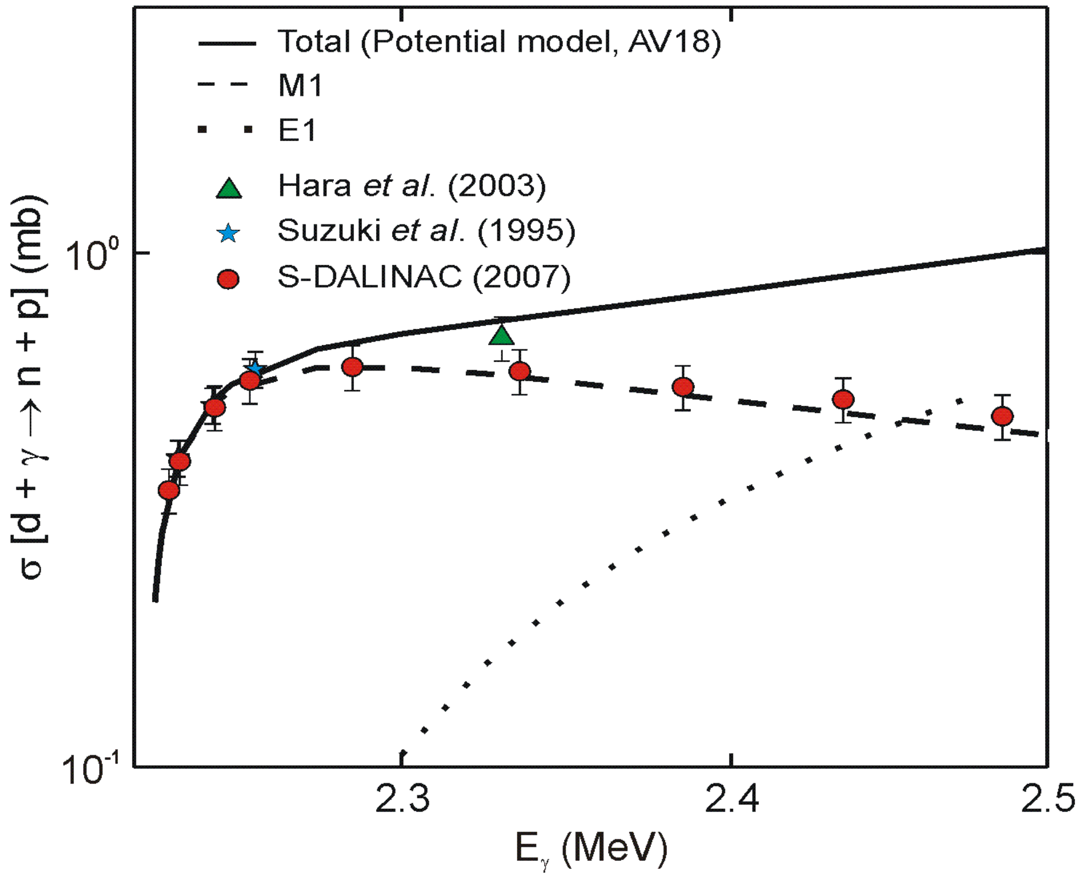
^{2}H(e,e') Reaction at 180°



N. Ryezayeva et al., PRL 100, 172501 (2008)

Relevance for Big-Bang Nucleosynthesis



- BBN relevant energy window
- Precision test of modern theoretical models (potential model, EFT)

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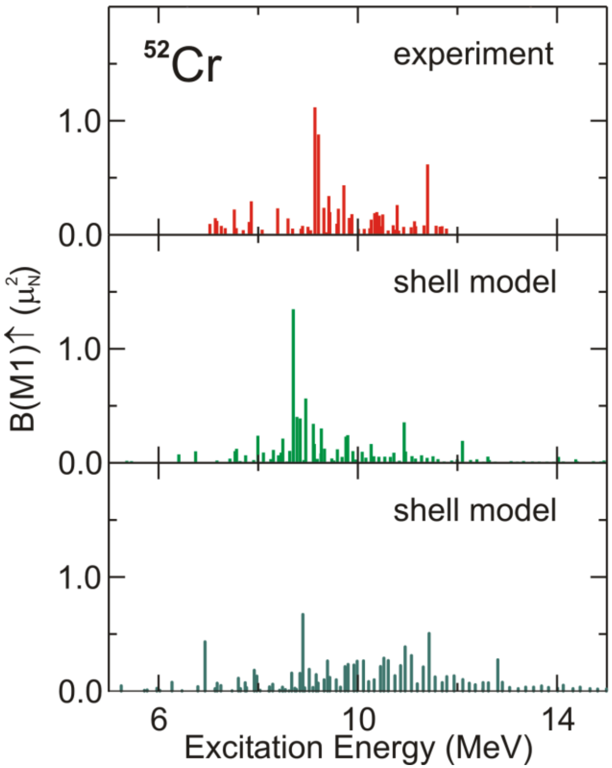
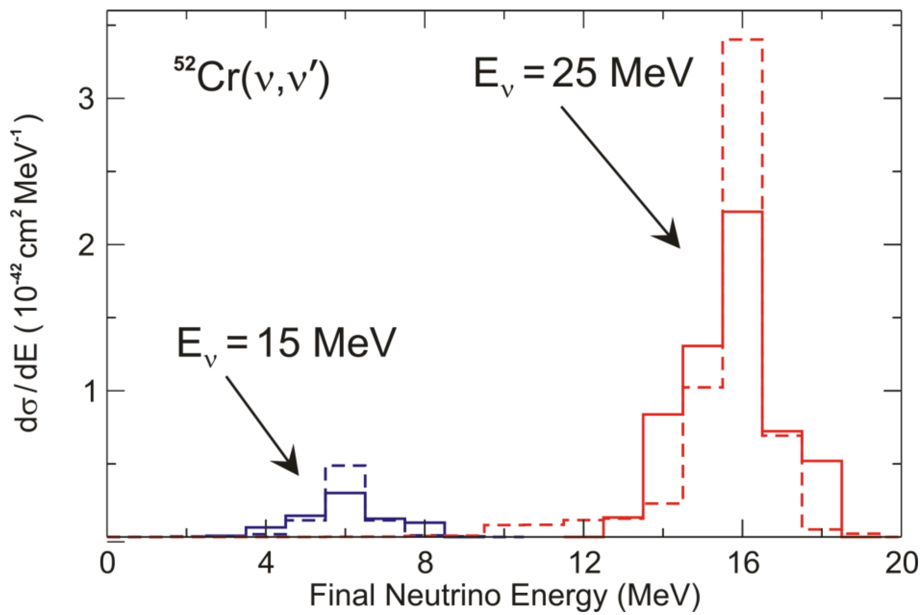
Neutral current reactions in supernovae

M1 Resonance in N = 28 Isotones and Neutrino-Nucleus Cross Sections

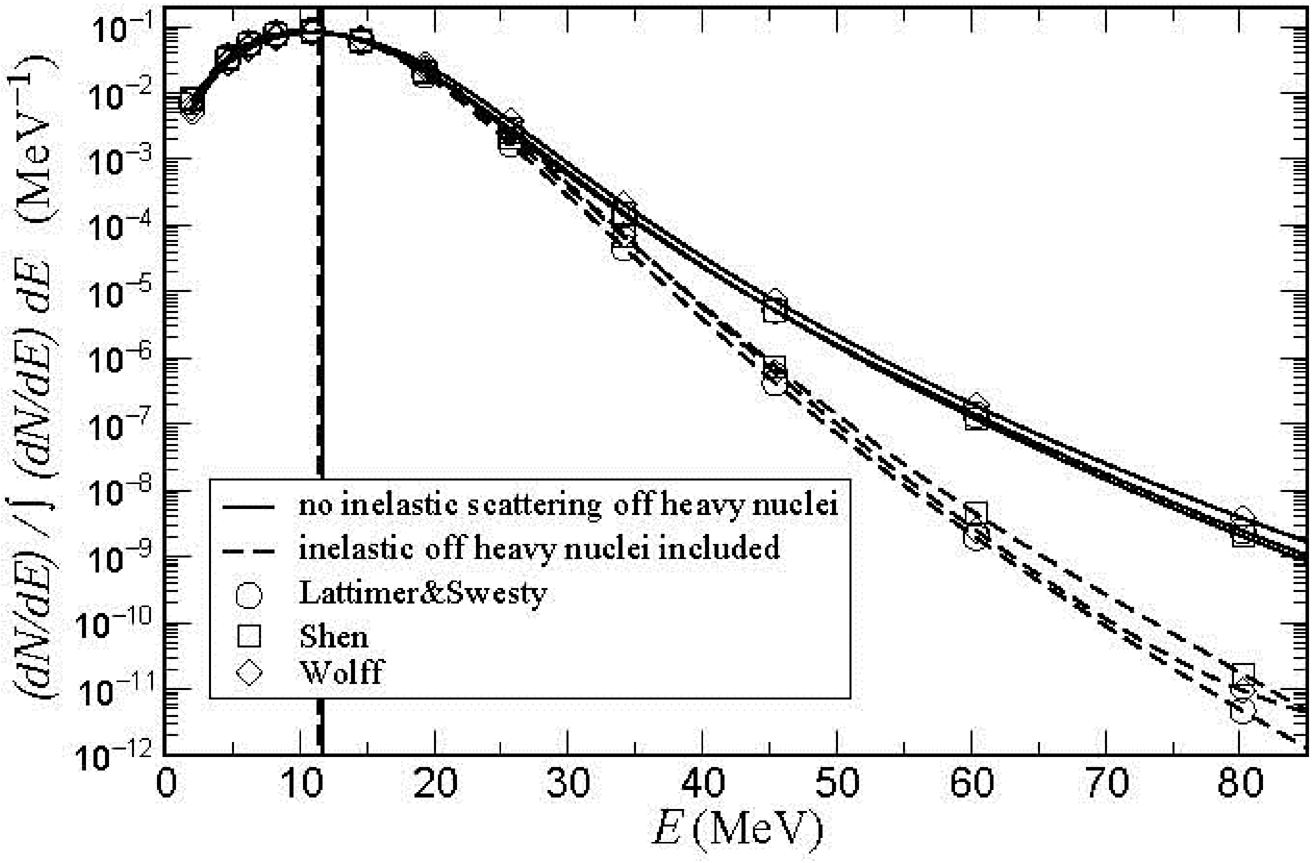
K. Langanke, G. Martínez-Pinedo, PvNC, A. Richter, Phys. Rev. Lett. 93, 202501 (2004)





Impact on Supernova Neutrino Spectra

K. Langanke et al., Phys. Rev. Lett. 100, 011101 (2008)



Quenching of the spin-isospin response

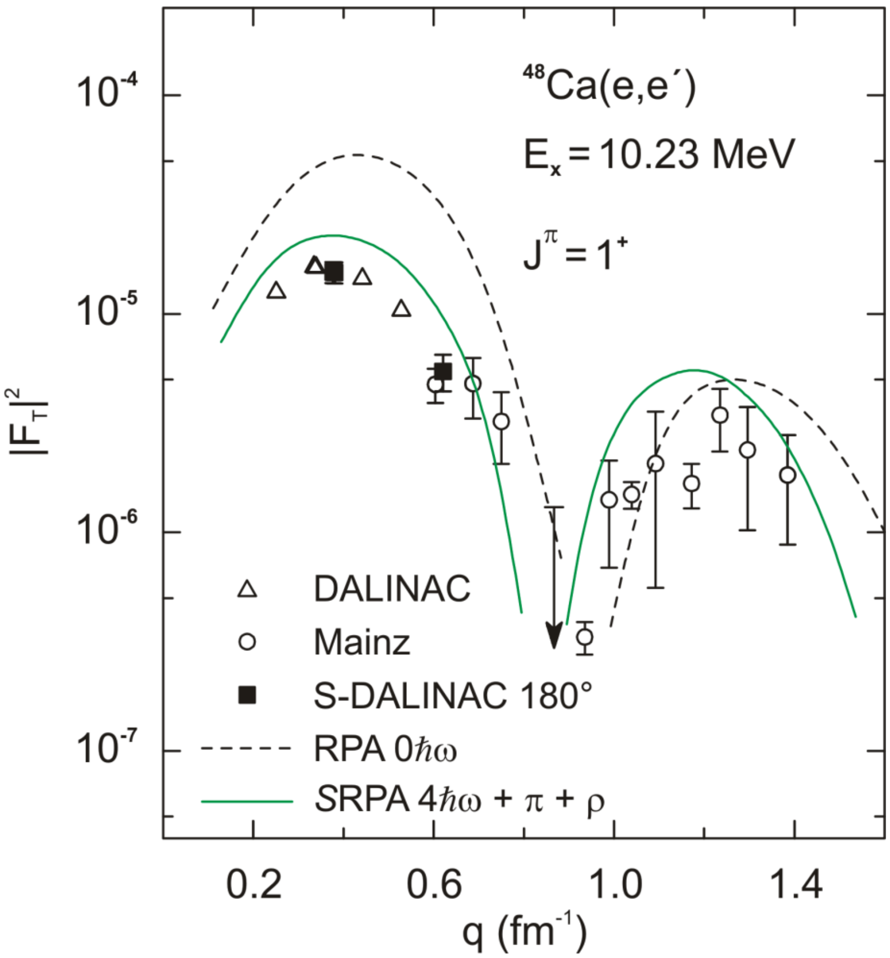
Comparison M1/GT Operator

$$T(M1)_{\text{iv}} = \sqrt{\frac{3}{4\pi}} \sum_i [\vec{l}_i \vec{t}_{zi} + (g_s^p - g_s^n) \vec{s}_i \vec{t}_{zi}] \mu_N$$

$$T(GT_0) = 2 \sum_i [\vec{s}_i \vec{t}_{zi}]$$

- spin part dominates because of anomalous magnetic moments
- isoscalar part weak

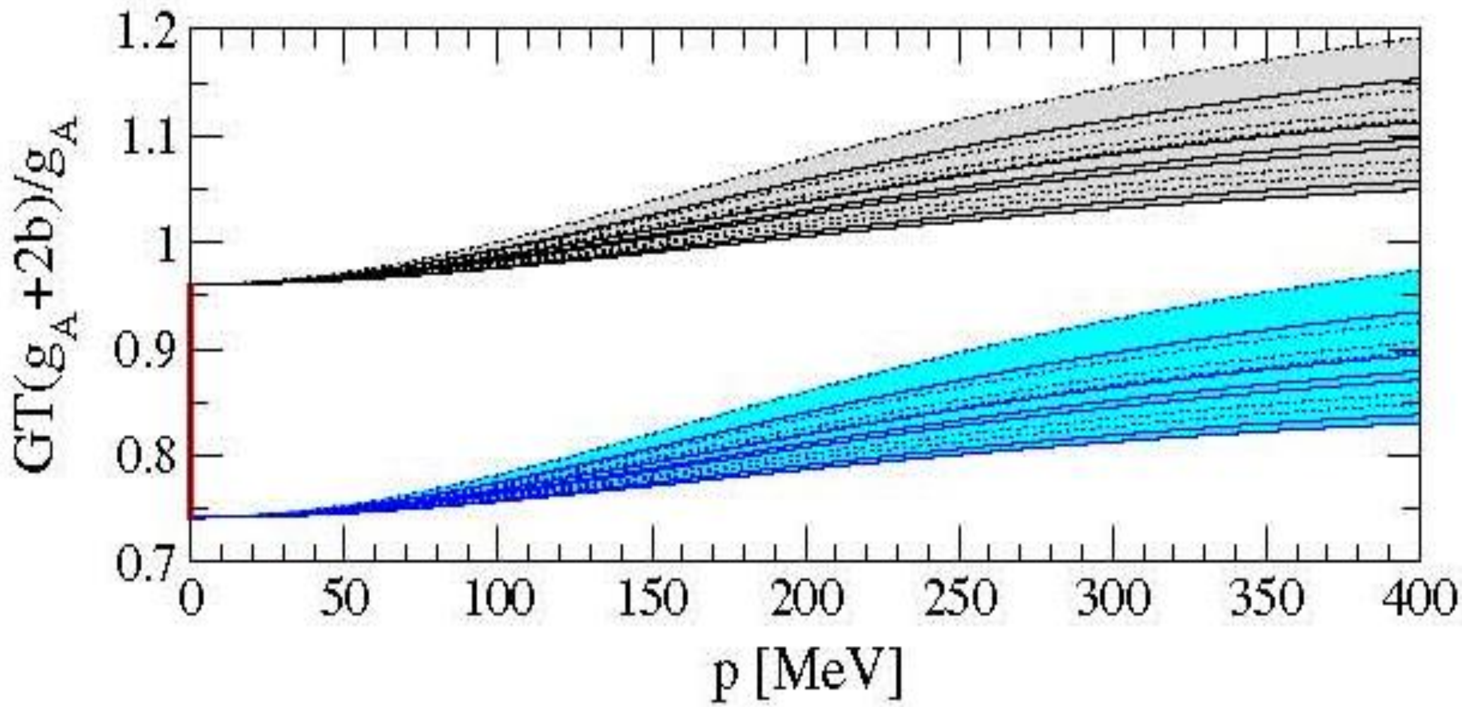
Spinflip M1 Transition in ^{48}Ca



- Spinflip transition
- Very strong: $B(M1)\uparrow \approx 4\ \mu_N^2$
- Test case for quenching

Momentum Transfer Dependence of GT Quenching

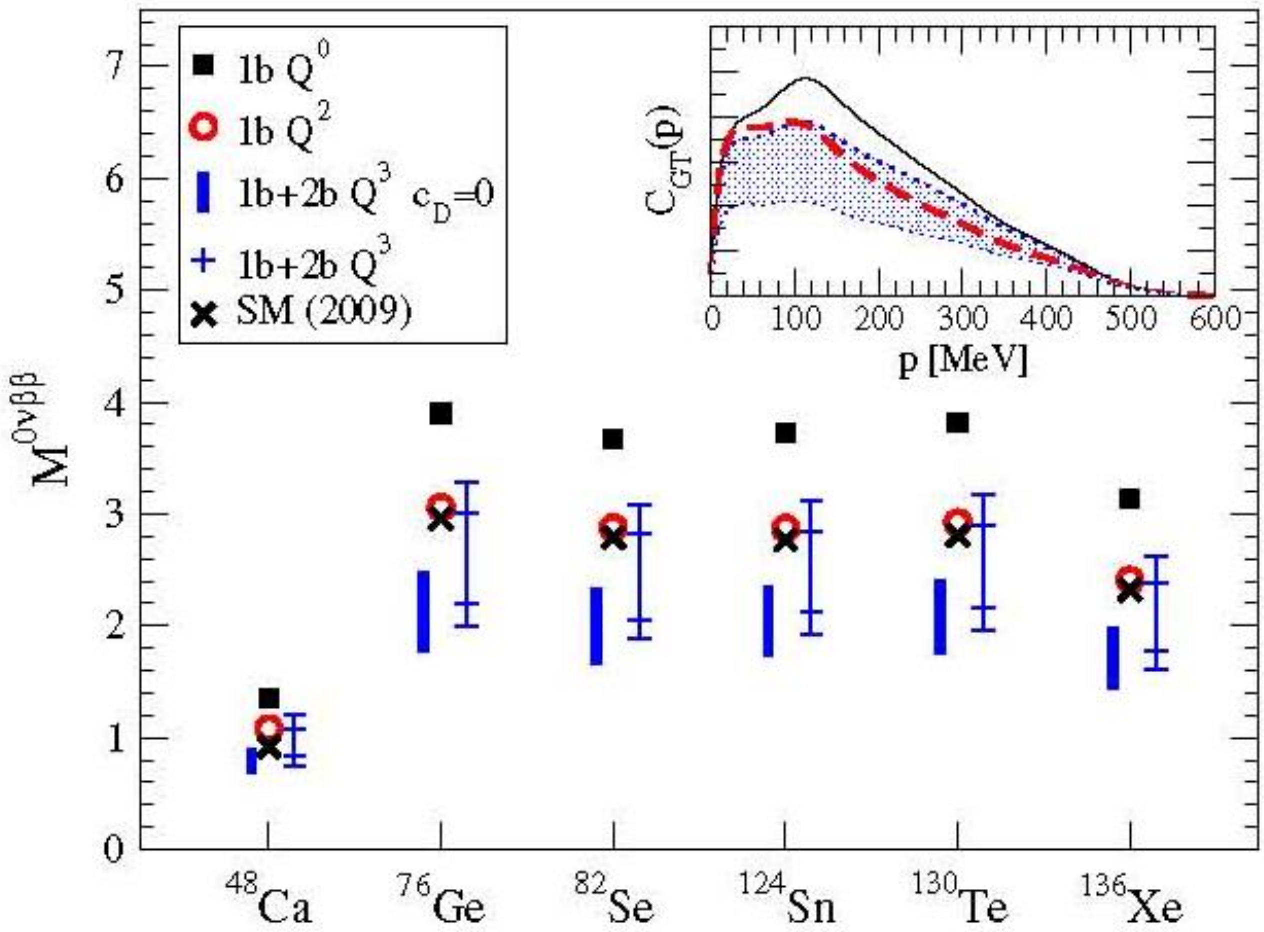
J. Menéndez, D. Gazit, A. Schwenk, Phys. Rev. Lett 107, 062501 (2011)



- Difficult (if not impossible) to test with hadronic probes
- Test of selected M1 cases with electron scattering
- Two-body currents differ (vector vs. axialvector coupling)

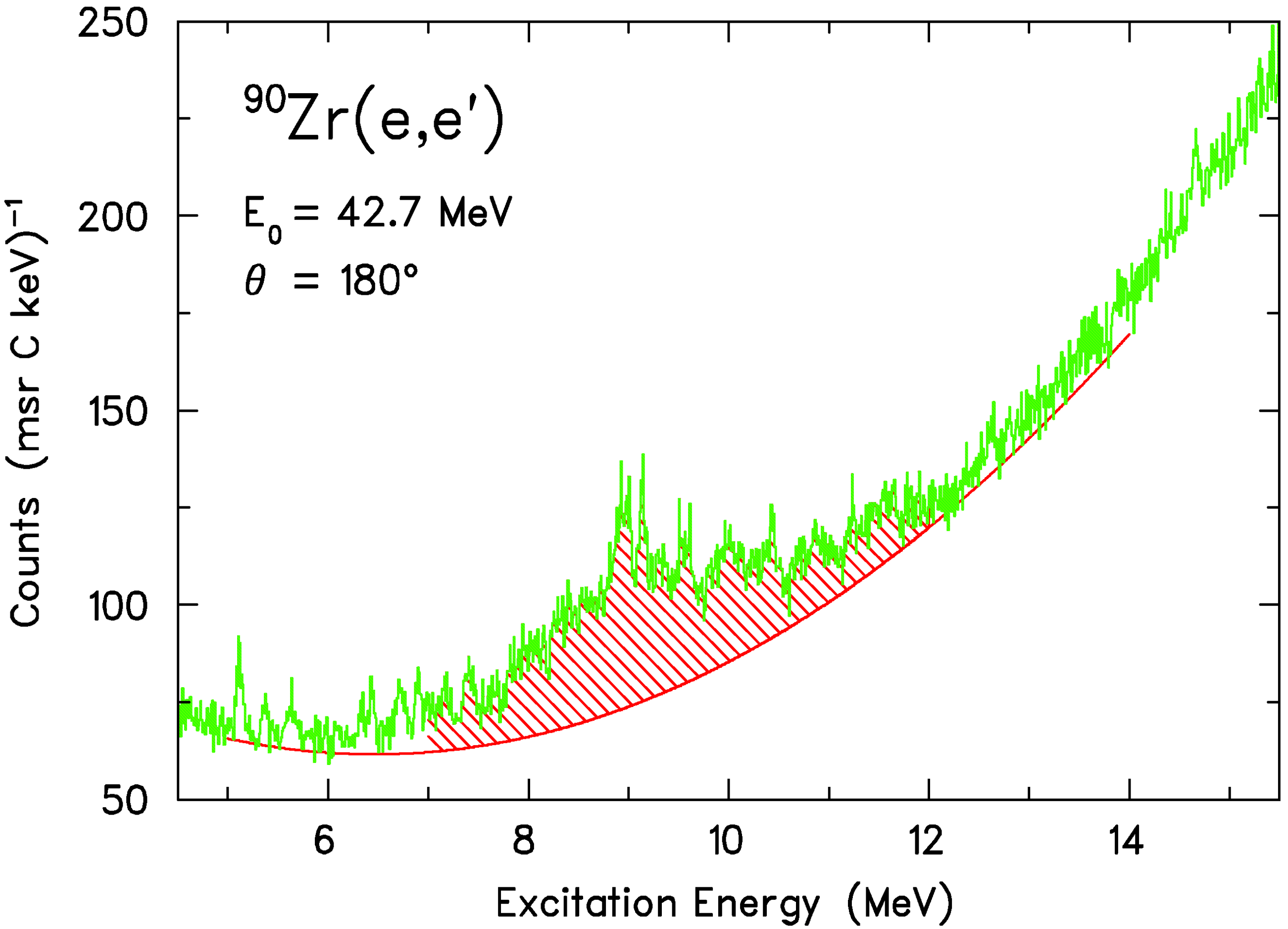
Impact on 0ββ Decay

J. Menéndez, D. Gazit, A. Schwenk, Phys. Rev. Lett 107, 062501 (2011)

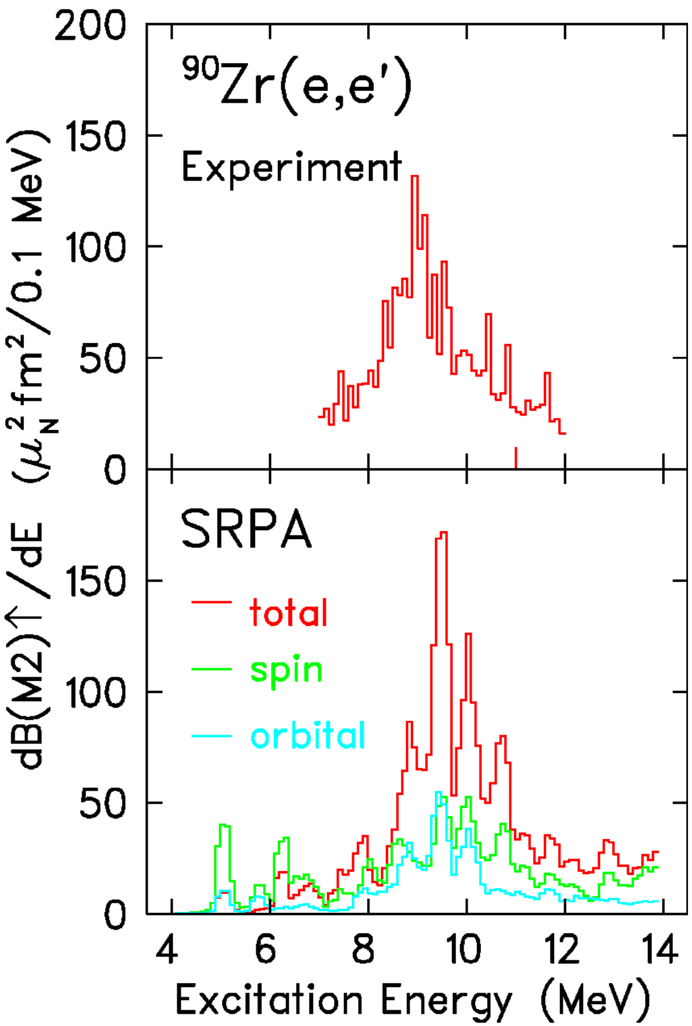


M2 Resonance in 180° Electron Scattering

PvNC et al., Phys. Rev. Lett. 82, 1105 (1999)



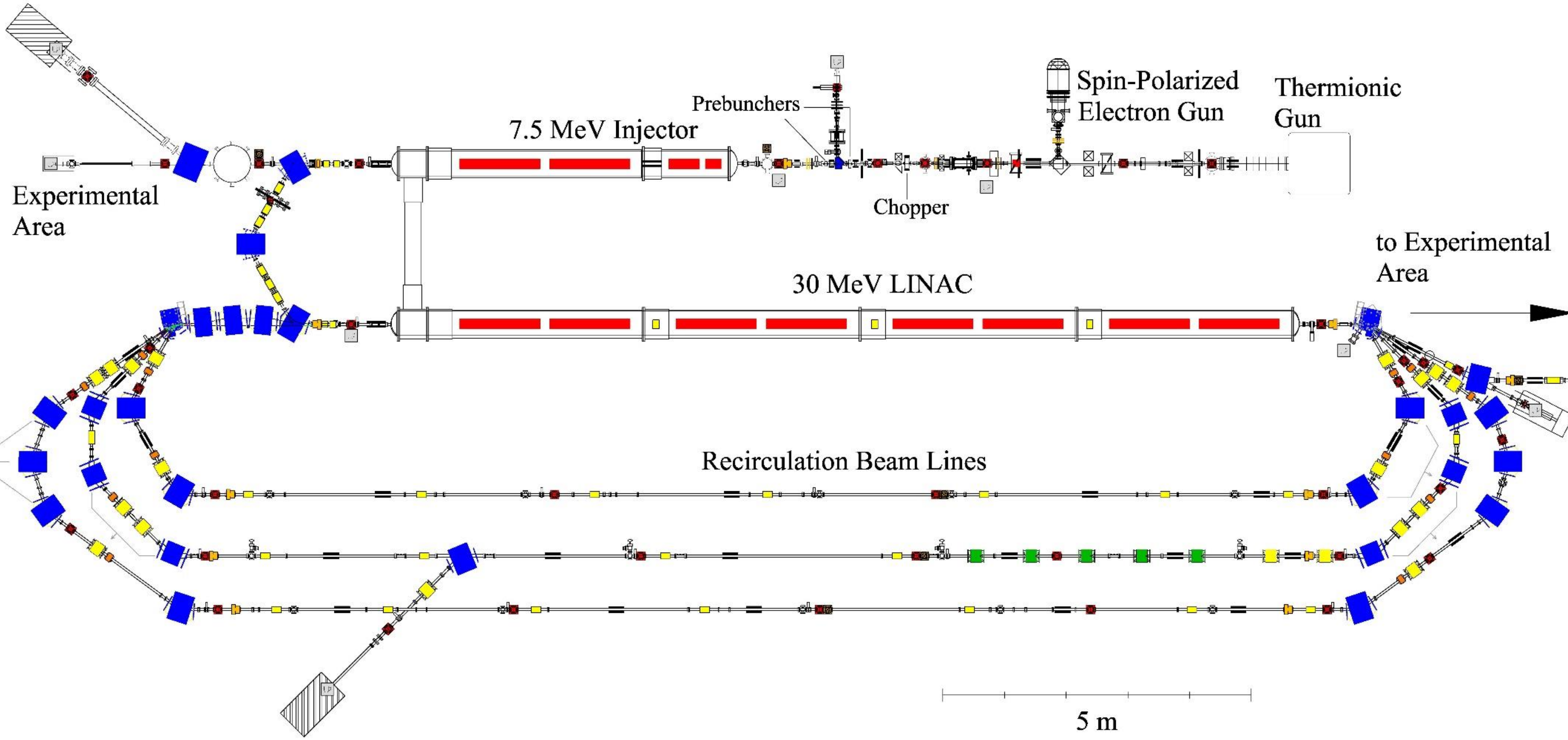
M2 Resonance in 180° Electron Scattering



- Strong spin/orbit interference
- Quantitative description possible with quenching comparable to M1

Future plans

S-DALINAC in 2016

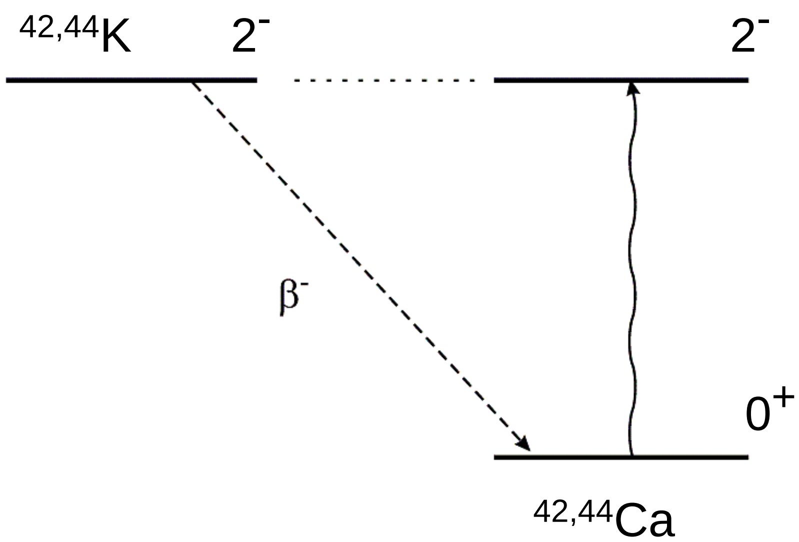


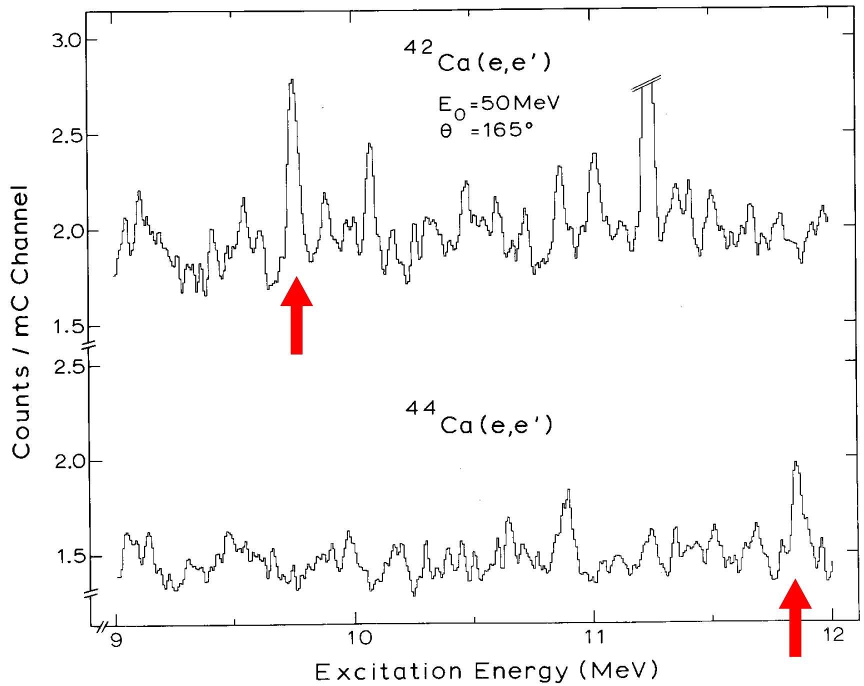
2016: $E_{max} \approx 130$ MeV

Study of energy recovery concept

Relation between Spin-M2 and First-Forbidden Matrix Elements

C. Rangacharyulu et al., Phys. Lett. B 135, 29 (1984)





Orbital matrix elements are zero within error bars

180° Experiments

- Systematic study of analog transitions to forbidden decay in light nuclei
  - M2 (first forbidden): ^{16}O, ^{42,44}Ca
  - M3 (second forbidden): ^{10}B, ^{22}Ne
  - M4 (third forbidden): ^{40}Ar, ^{40}Ca

- Momentum transfer dependence of quenching: ^{40,48}Ca

- ^{12}C (cluster structure), ^{14}C

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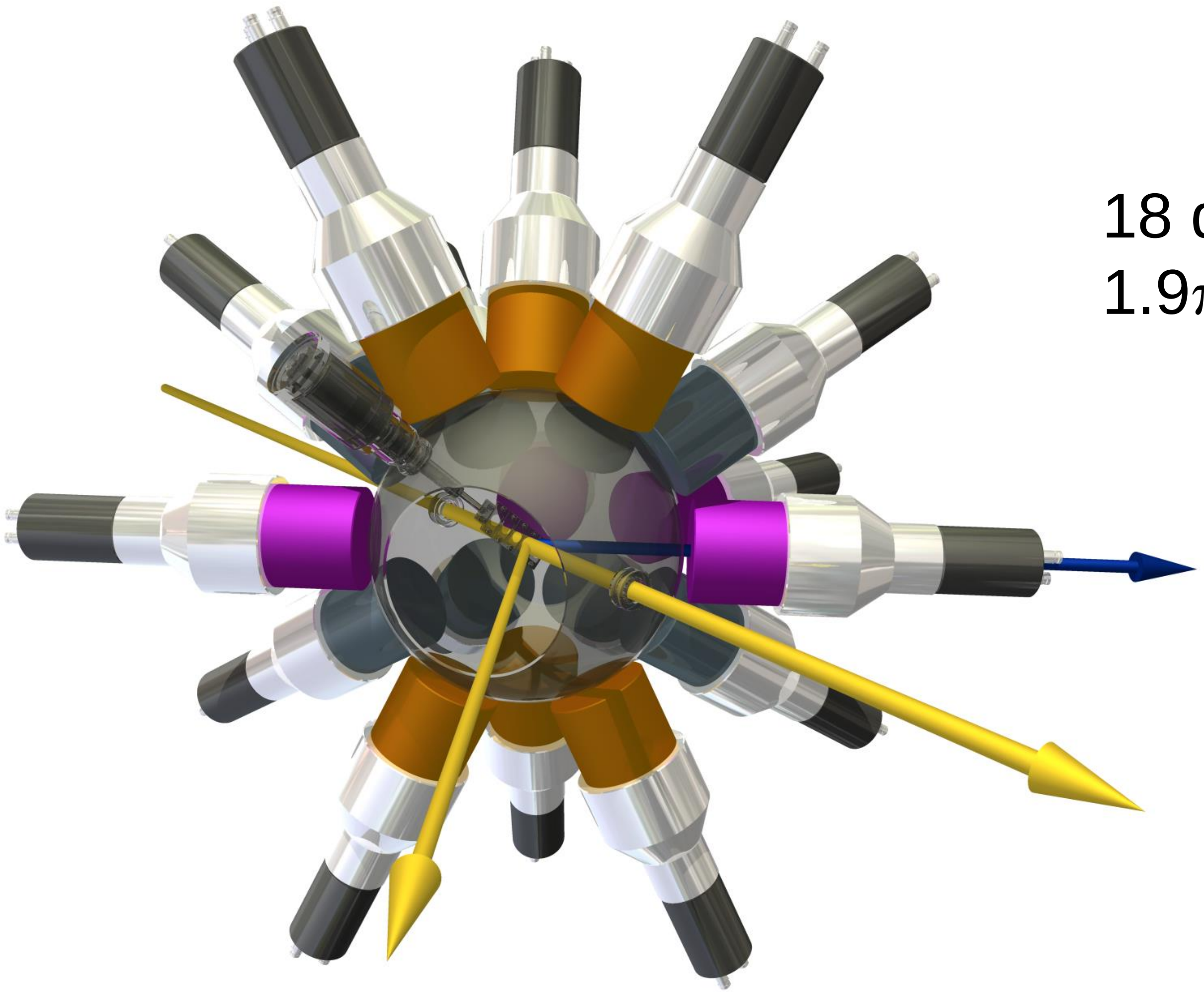
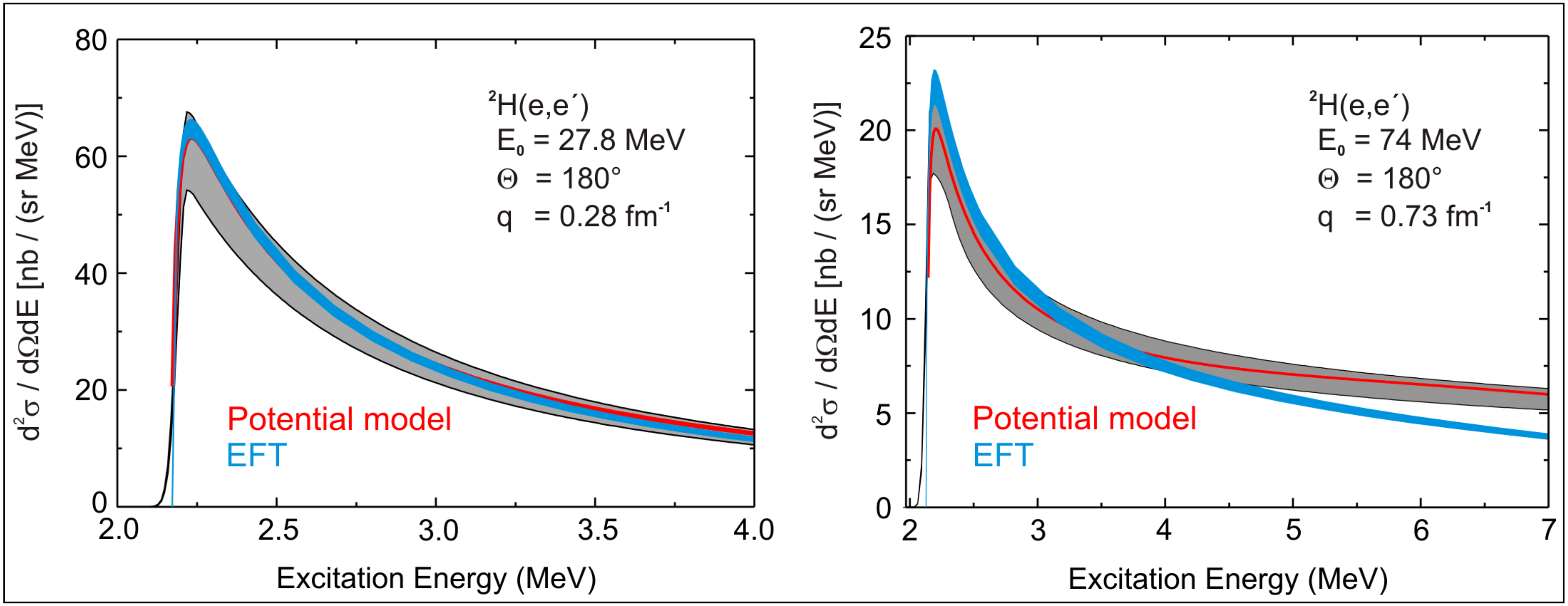
Thank you for your attention!

$LaBr_3$ Ball for (e,e‘γ) Experiments



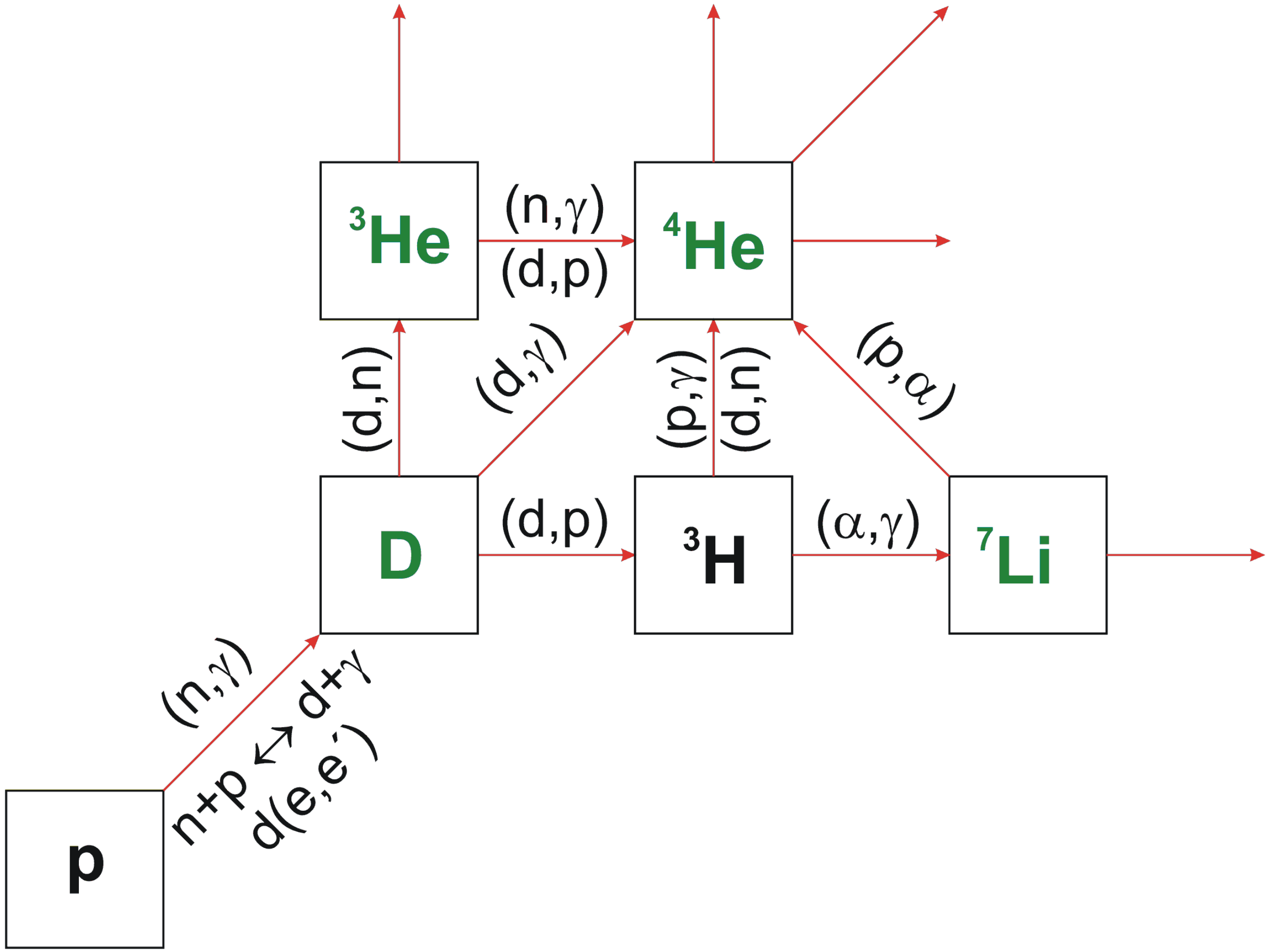
18 detectors 3“ x 3“
1.9π solid angle

Comparison to Potential Model and EFT Calculations



- Excellent agreement with potential model (H. Arenhövel)
- Deviations to pionless EFT (H. Griesshammer) at higher momentum transfer
- Extrapolation to photon point → equivalent (γd → np) cross sections

Primordial Nucleosynthesis



Spin-Dipole Strength

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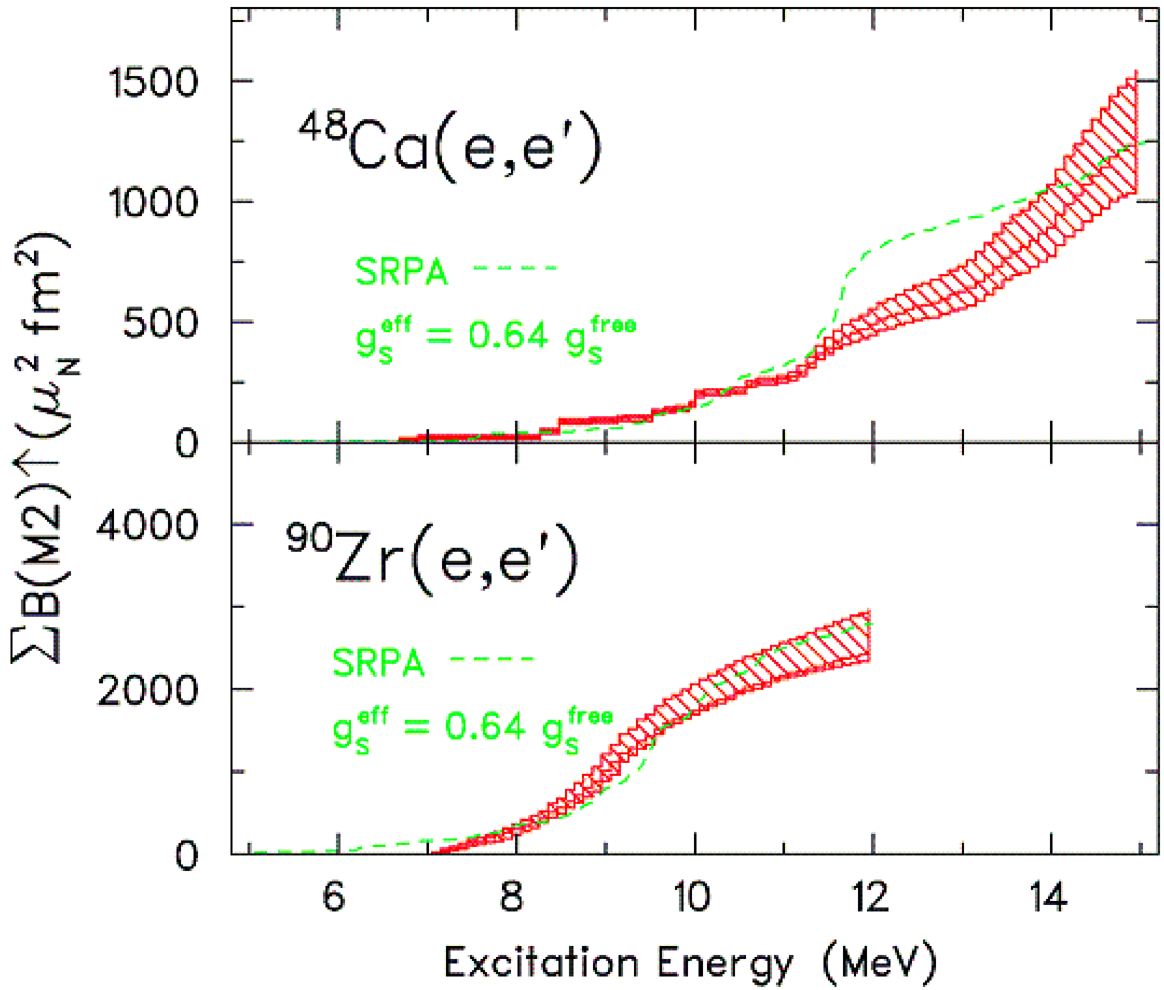
- Spin dipole: $\Delta L = 1$, $\Delta S = 1$, $\Delta T = 1$, $J^{\pi} = 0^-, 1^-, 2^-$
- 0^- states cannot be excited in (e,e') → M0 transition
- 1^- states → transverse E1 strength
- 2^- states → M2 strength
- Relation spin M2 / unique first-forbidden operator similar to M1 / GT

M2 Strength: Running sums



Quenching comparable to M1