Investigation of dipole strength functions at the ELBE accelerator in Dresden

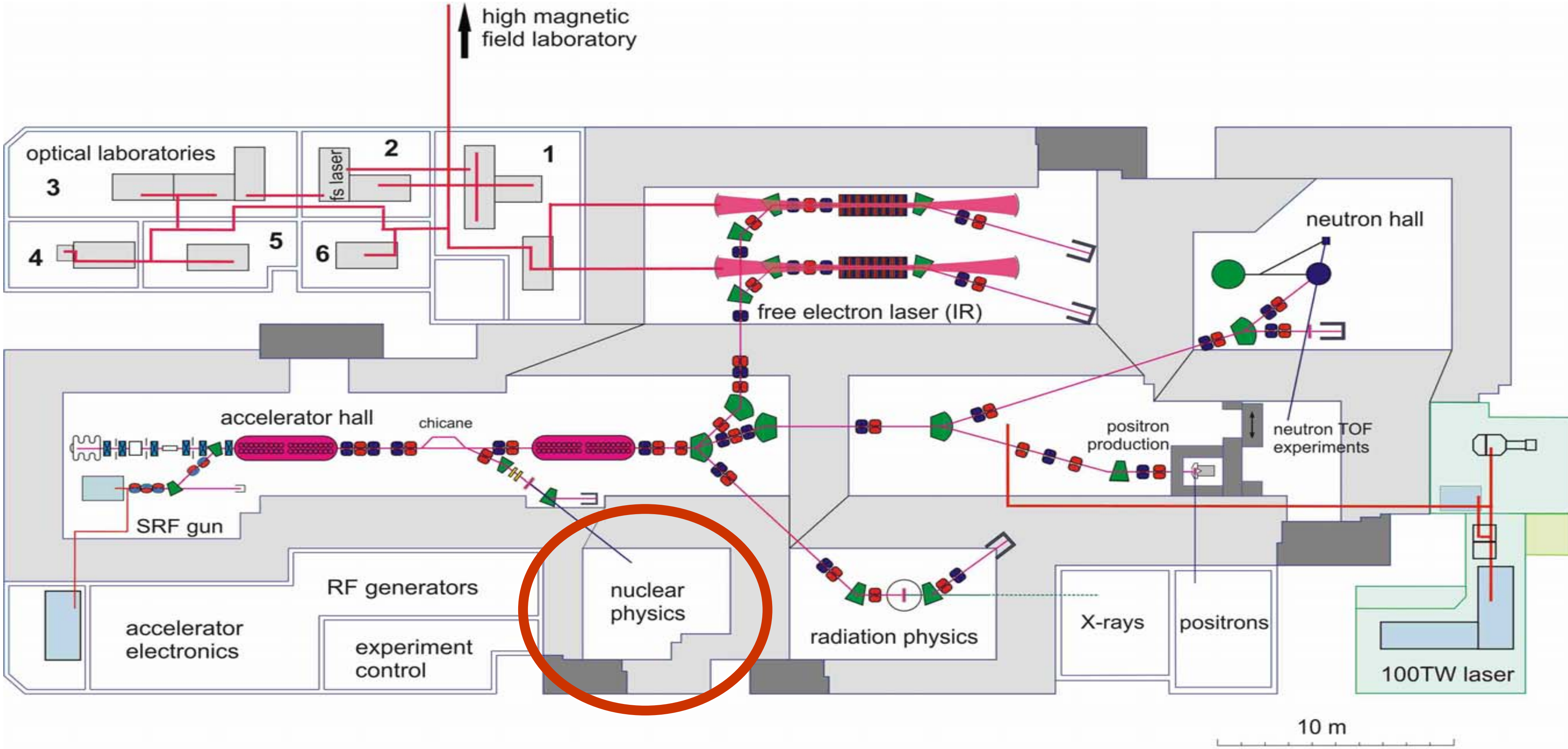
Ralph Massarczyk

Forschungszentrum Dresden Rossendorf

content

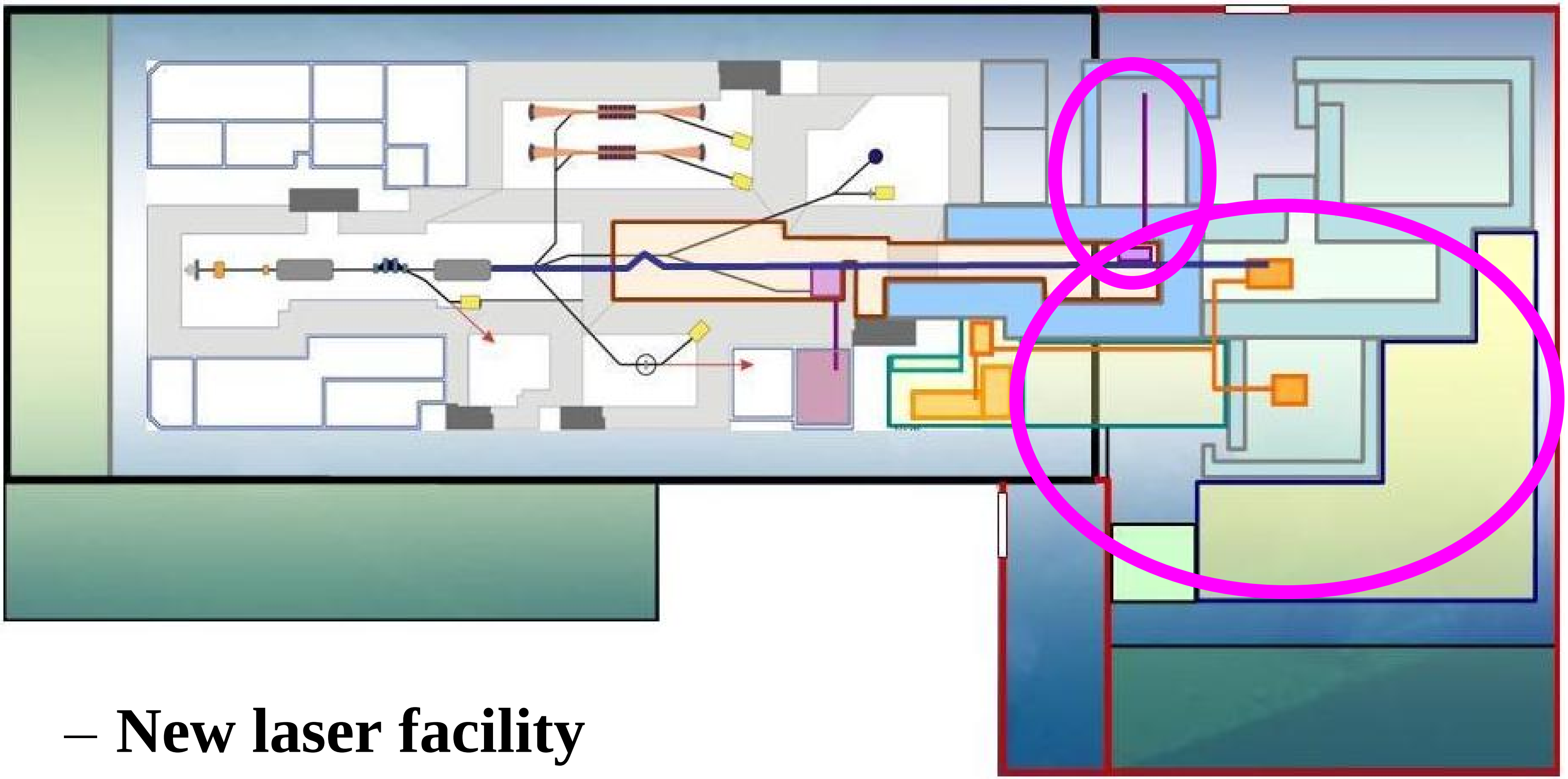
- **Overview of the facility**
- **Experiment on ^{136}Ba**
  - Data analysis
  - Geant4 simulations
- **Experiments on ^{86}Kr**
  - Comparison with other N = 50 nuclei

Electron Linac for beams with high Brilliance and low Emittance



1: Diagnostic station, IR-imaging and biological IR experiment
2: Femtosecond laser, THz-spectroscopy, IR pump-probe experiment
3: Time-resolved semiconductor spectroscopy, THz-spectroscopy
4: FTIR, biological IR experiment
5: Near-field and pump-probe IR experiment
6: Radiochemistry and sum frequency generation experiment, photothermal deflection spectroscopy

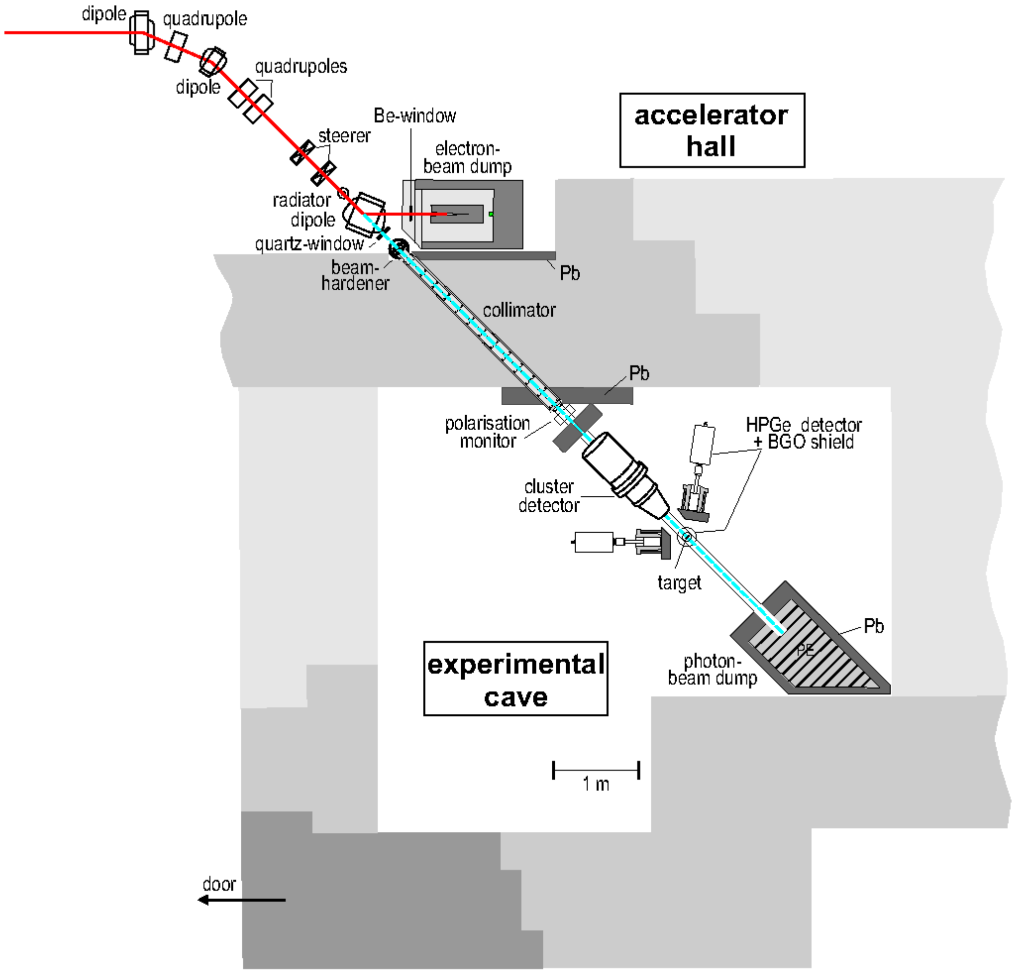
Extension of ELBE



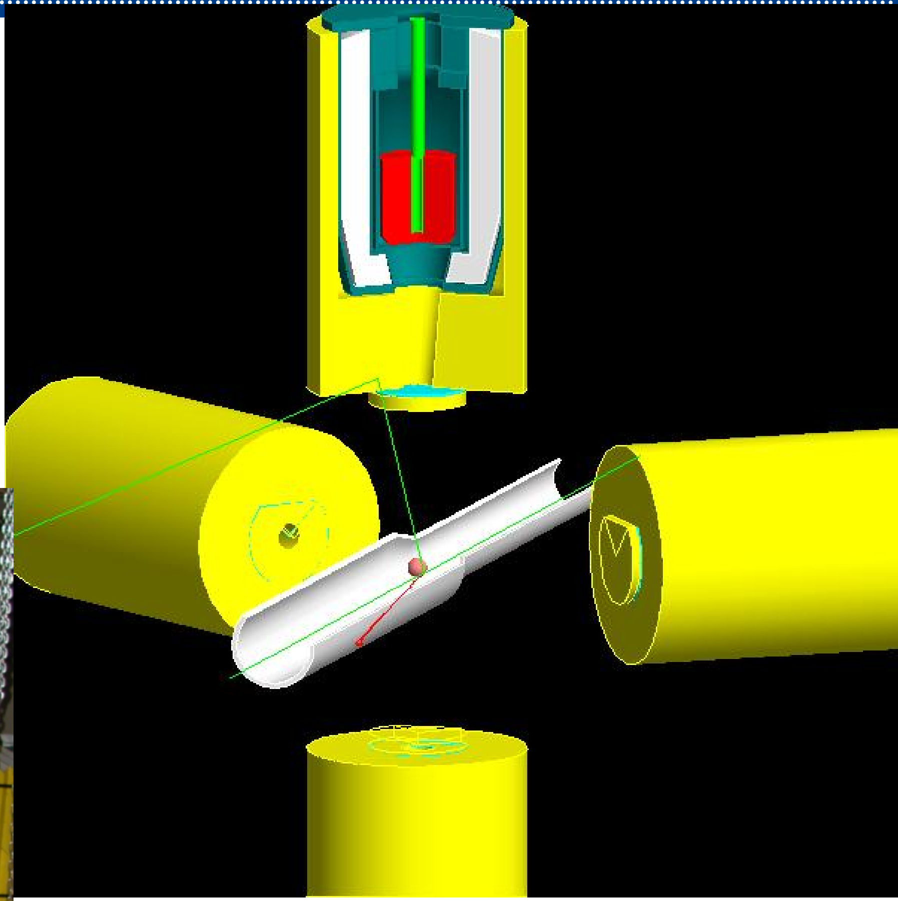
– **New laser facility**
– **New neutron facility**

Bremsstrahlung at ELBE

- Accelerator parameters:
  - Maximum electron energy: 18 MeV
  - Maximum average current: 1 mA
  - Operation in cw mode $f = 26 / 2^n$ MHz
- Bremsstrahlung produced in 2 - 12 µm Niobium foil
- through collimator on target beam spot ø 2 cm



- Setup for nuclear resonance fluorescence:
  - 4 High purity Germanium detectors (at 90° and 127° to the beam)
  - Each with escape suppression by BGO shields



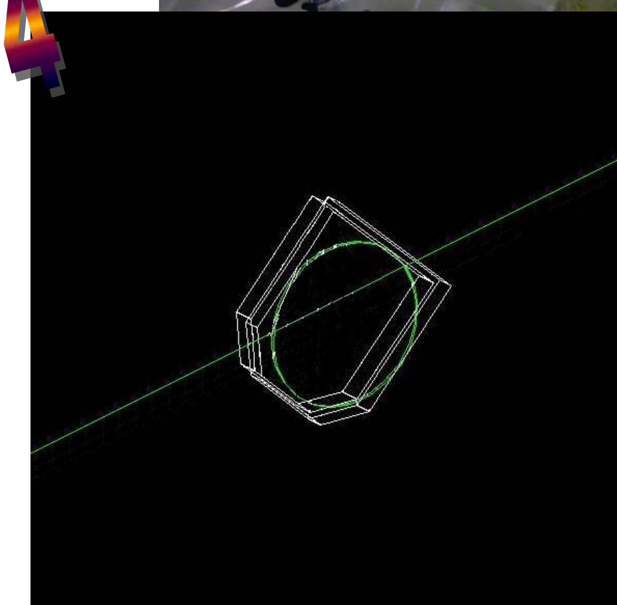
R. Schwengner et al., NIM A 555 (2005) 211

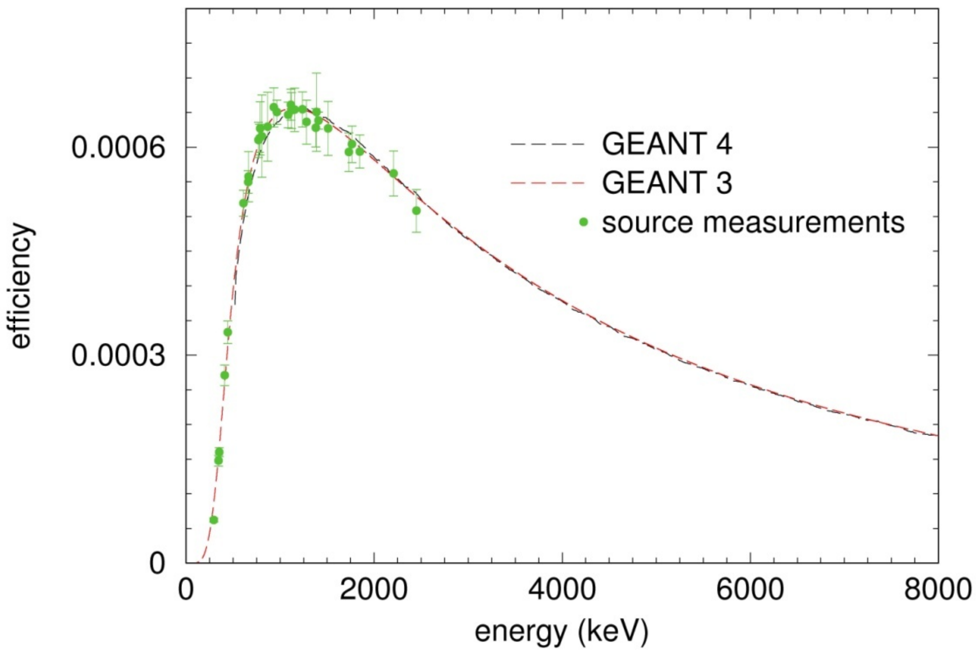
Experiment on ^{136}Ba

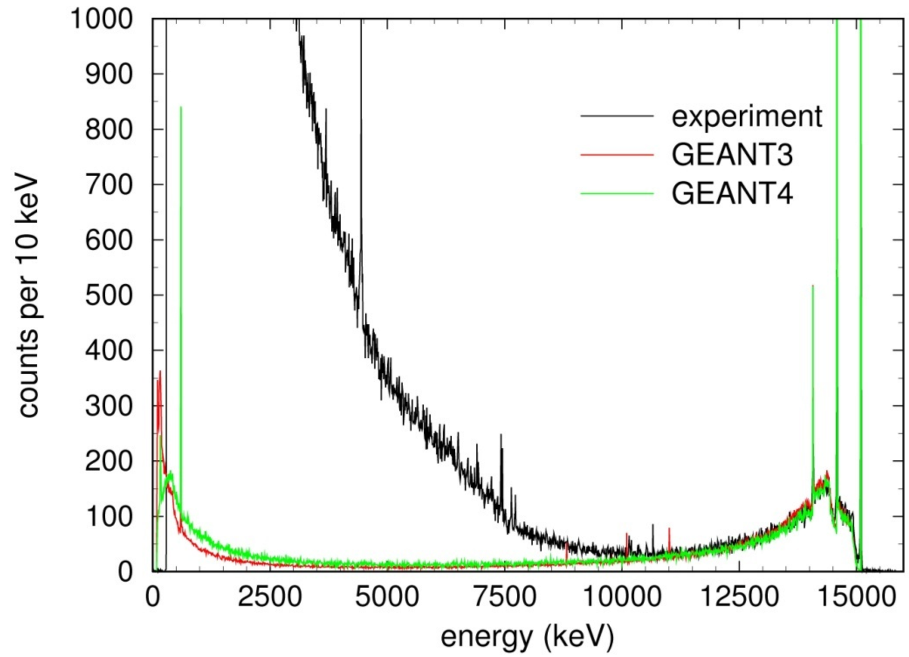
$$I_S = \frac{n_{cal}}{n_{target}} \cdot \left(\frac{\Phi_\gamma \epsilon(E,\theta) W(\theta) I_S}{A(\theta)}\right)^{cal} \cdot \left(\frac{A(\theta)}{\Phi_\gamma \epsilon(E,\theta) W(\theta)}\right)^{target}$$

- Calculation of integrated cross sections relative to known cross section in ^{11}B
- Angular correlation and number of nuclei
- Measured intensities
  - Subtraction of non-nuclear scattered events
  - Correction for Detector response
- Detector efficiency for angle and energy
- Flux on target, energy dependent

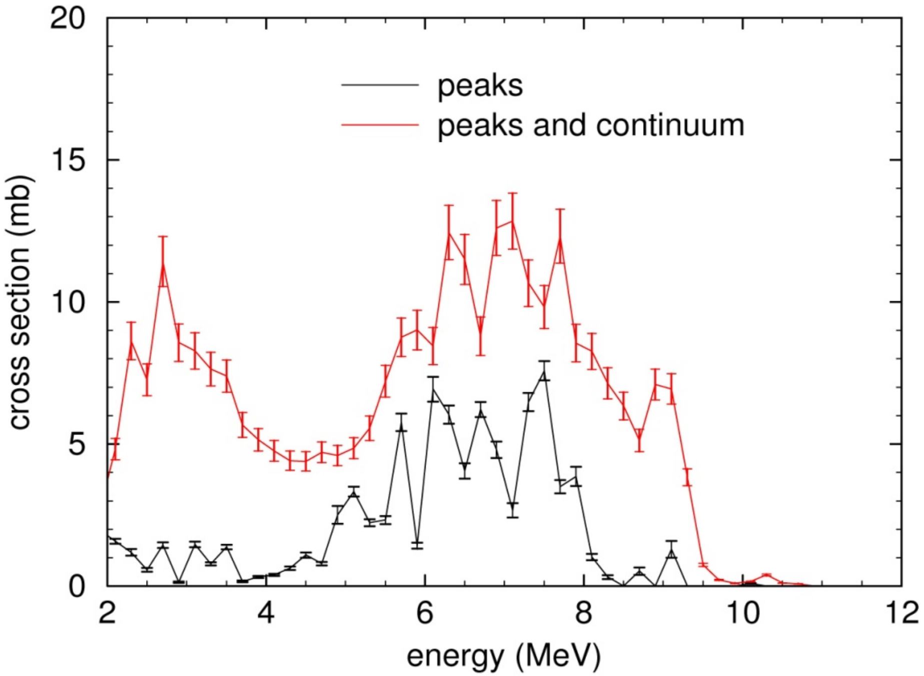
Simulation in GEANT4

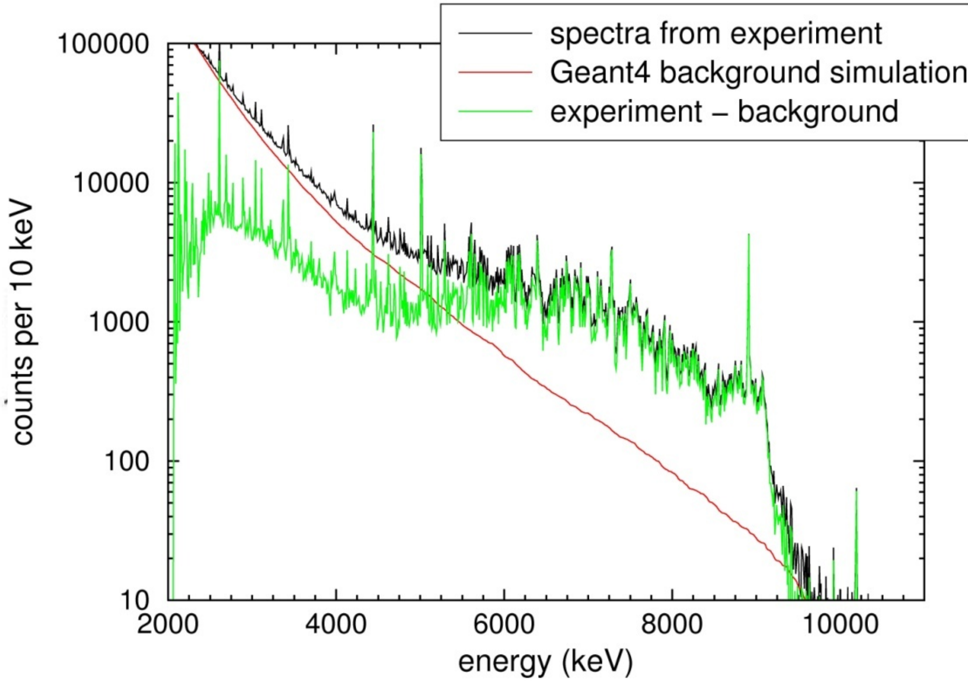




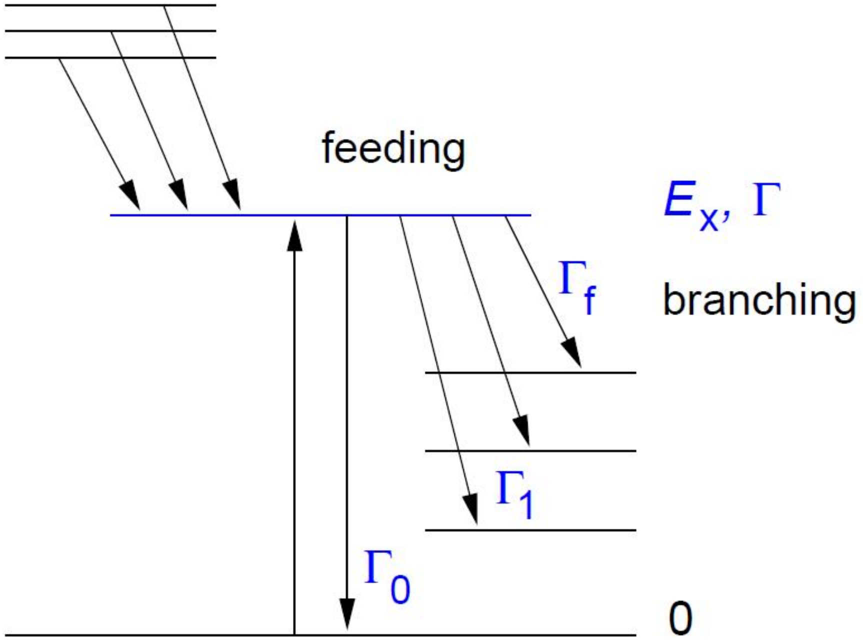


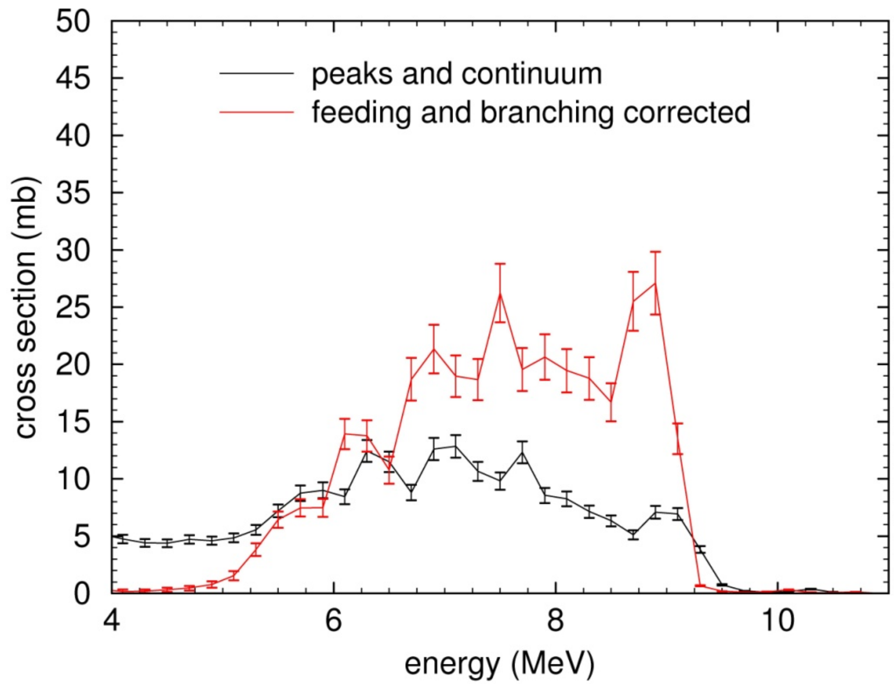
- Efficiency simulation up to the neutron-separation energy
- Simulation and correction for detector response
- GEANT3 simulations by G.Rusev (PhD thesis 2007 TU Dresden)
- GEANT3 and GEANT4 are consistent



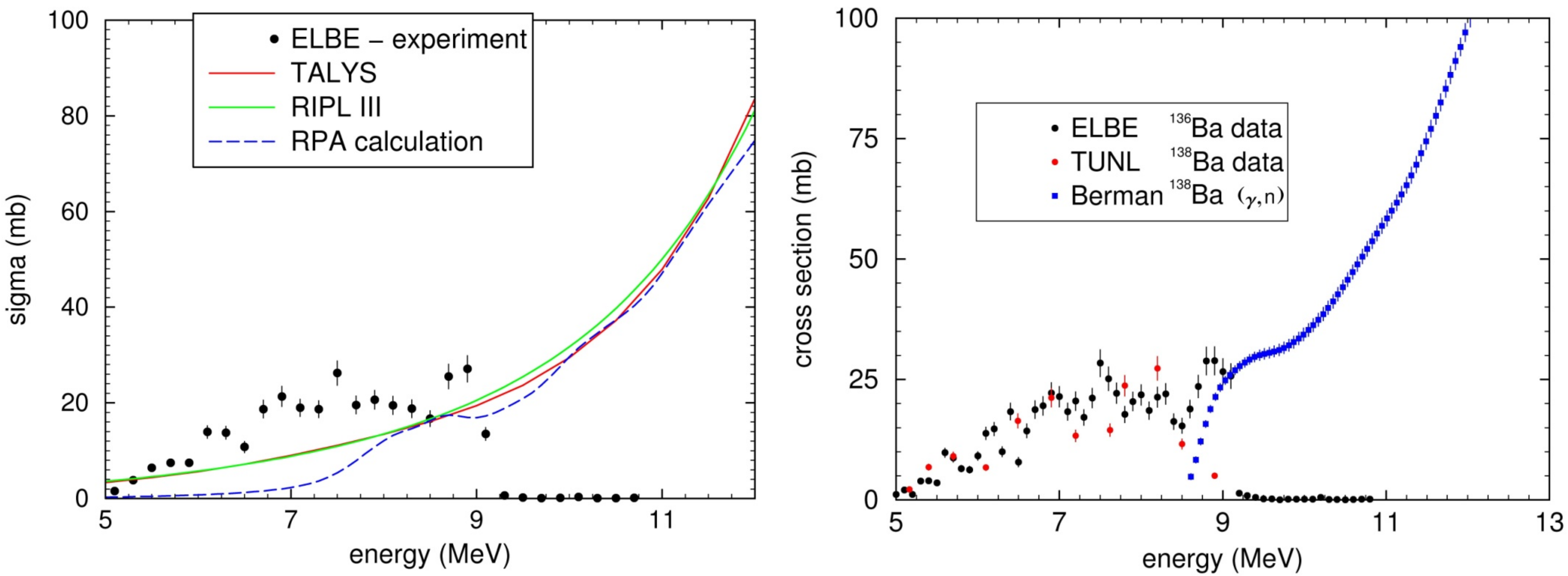


- Identification of dipole transitions by angular distributions
- Simulation of non-nuclear scattered events in GEANT4





- Feeding and branching correction needed
- Analog to branching correction in (n, γ) - experiments
- γ -ray cascades have to be simulated and applied to the measured spectra
- Subtraction of intensities of inelastic transitions
- Correction of the intensities of the ground-state transitions
  for their branching ratios



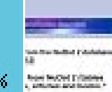
- Talys calculation 3 Lorentzian and M1 (Junghans et al. PLB 670 (2008) 200) and (Heyde et al , ArXiv:1004.3429v2, April 2010)
- RPA calculation by F. Dönau
- ^{138}Ba *(γ,γ')* measurement at Hiγs (Tonchev et al. PRL 104, 072501 (2010))
- *(γ,n)* data from Berman (Berman et al. Phys. Rev. C2, 2318(1970))

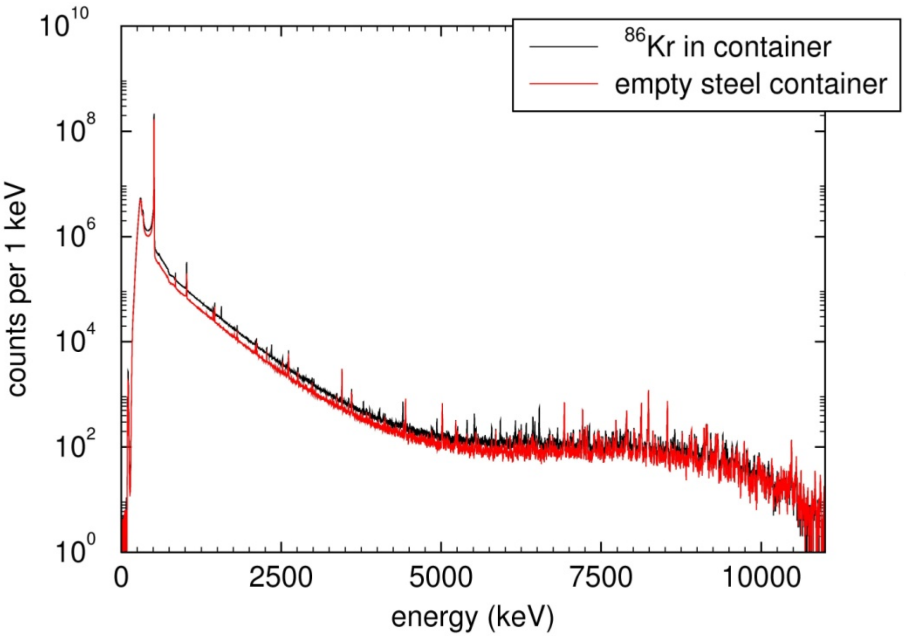
- Additional strength relative to analytic extrapolations of the GDR between about 5 and 9 MeV

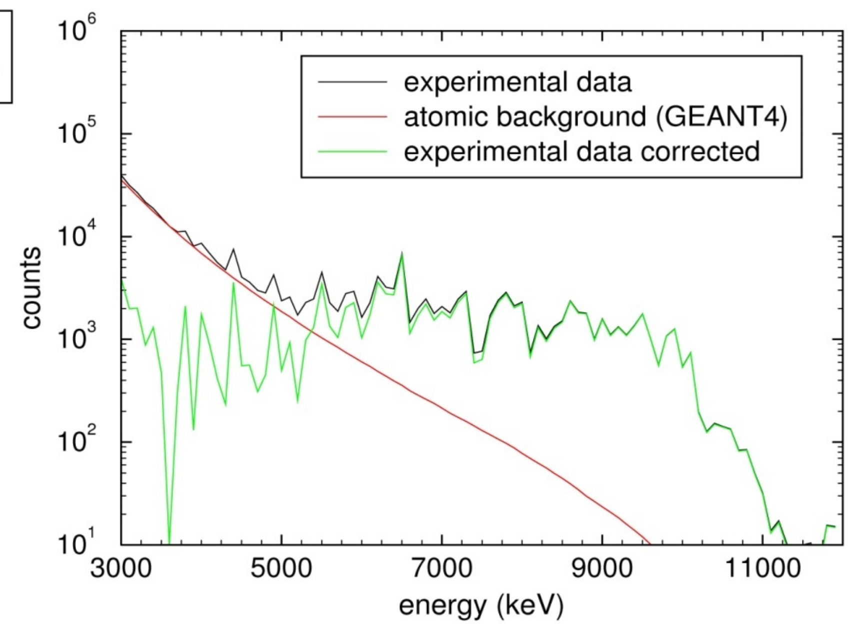
Experiments on ^{86}Kr

^{86}Kr

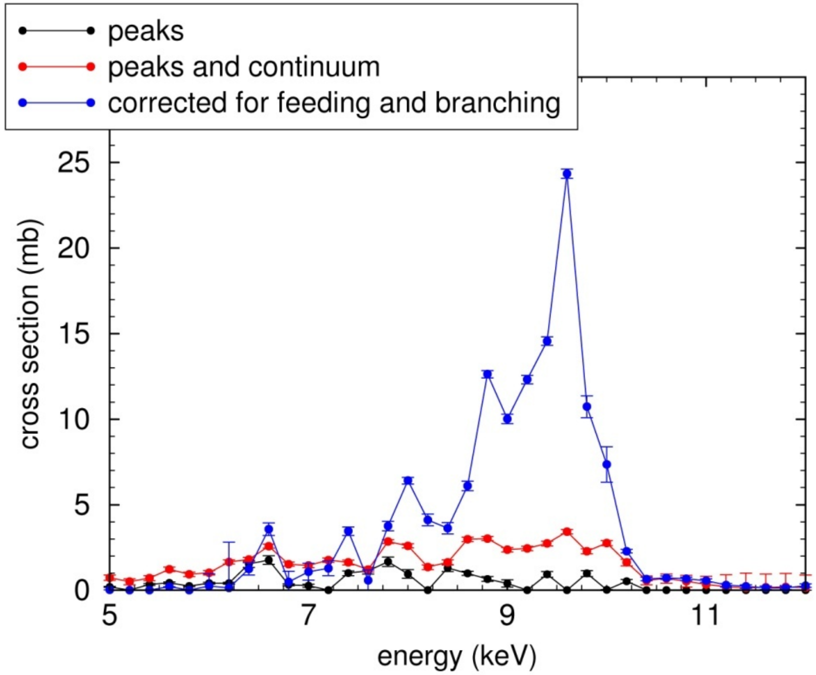
Mo M .00%	89Mo 2.11 M ε: 100.00%	90Mo 5.56 H ε: 100.00%	91Mo 15.49 M ε: 100.00%	92Mo STABLE 14.84%	93Mo 4.0E+3 Y 100.00%	94Mo STABLE 9.25%	95Mo STABLE 15.92%	96Mo STABLE 16.68%	97Mo STABLE 9.55%	98Mo STABLE 24.13%
Nb 5 M .00%	88Nb 14.55 M ε: 100.00%	89Nb 2.03 H ε: 100.00%	90Nb 14.60 H ε: 100.00%	91Nb 6.8E+2 Y ε: 100.00%	92Nb 3.47E+7 Y ε: 100.00% β-: <0.05%	93Nb STABLE 100%	94Nb 2.03E+4 Y β-: 100.00%	95Nb 34.991 D β-: 100.00%	96Nb 23.35 H β-: 100.00%	97Nb 72.1 M β-: 100.00%
Zr 5 H .00%	87Zr 1.68 H ε: 100.00%	88Zr 83.4 D ε: 100.00%	89Zr 78.41 H ε: 100.00%	90Zr STABLE 51.45%	91Zr STABLE 11.22%	92Zr STABLE 17.15%	93Zr 1.53E+6 Y β-: 100.00%	94Zr STABLE 17.38%	95Zr 64.032 D β-: 100.00%	96Zr >3.9E+20 Y 2.80% 2β-
Y 3 H .00%	86Y 14.74 H ε: 100.00%	87Y 79.8 H ε: 100.00%	88Y 106.626 D ε: 100.00%	89Y STABLE 100%	90Y 64.0 3 H β-: 100.00%	91Y 58.51 D β-: 100.00%	92Y 3.54 H β-: 100.00%	93Y 10.18 H β-: 100.00%	94Y 18.7 M β-: 100.00%	95Y 10.3 M β-: 100.00%
Sr BLE 6%	85Sr 64.84 D ε: 100.00%	86Sr STABLE 9.86%	87Sr STABLE 7.00%	88Sr STABLE 82.58%	89Sr 50.5 D β-: 100.00%	90Sr 28.90 Y β-: 100.00%	91Sr 9.63 H β-: 100.00%	92Sr 2.66 H β-: 100.00%	93Sr 7.423 M β-: 100.00%	94Sr 75.3 S β-: 100.00%
Rb 2 D .00%	84Rb 33.1 D ε: 96.20% β-: 3.80%	85Rb STABLE 72.17%	86Rb 18.642 D β-: 99.99% ε: 5.2E-3%	87Rb 4.81E+10 Y 27.83% β-: 100.00%	88Rb 17.773 M β-: 100.00%	89Rb 15.15 M β-: 100.00%	90Rb 158 S β-: 100.00%	91Rb 58.4 S β-: 100.00%	92Rb 4.492 S β-: 100.00% β-n: 0.01%	93Rb 5.84 S β-: 100.00% β-n: 1.39%
Kr BLE 58%	83Kr STABLE 11.49%	84Kr STABLE 57.00%	85Kr 3916.8 D β-: 100.00%	86Kr STABLE 17.30%	87Kr 76.3 M β-: 100.00%	88Kr 2.84 H β-: 100.00%	89Kr 3.15 M β-: 100.00%	90Kr 32.32 S β-: 100.00%	91Kr 8.57 S β-: 100.00%	92Kr 1.840 S β-: 100.00% β-n: 0.03%
Br BLE 31%	82Br 35.282 H β-: 100.00%	83Br 2.40 H β-: 100.00%	84Br 31.80 M β-: 100.00%	85Br 2.90 M β-: 100.00%	86Br 55.1 S β-: 100.00%	87Br 55.65 S β-: 100.00% β-n: 2.60%	88Br 16.29 S β-: 100.00% β-n: 6.58%	89Br 4.40 S β-: 100.00% β-n: 13.80%	90Br 1.91 S β-: 100.00% β-n: 25.20%	91Br 0.541 S β-: 100.00% β-n: 20.00%

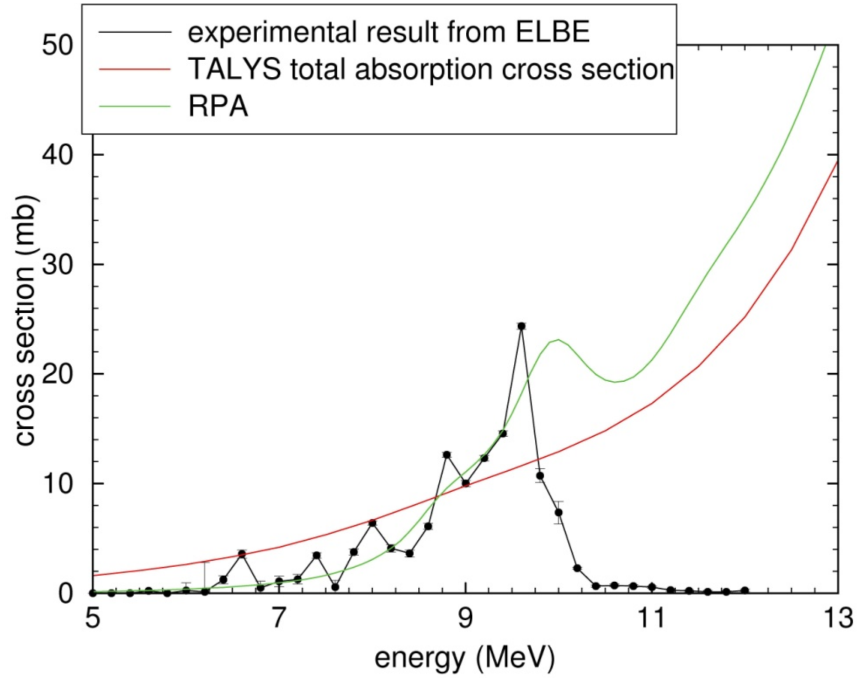






- ^{86}Kr complements a systematic study of stable isotones at the shell closure of neutron number N = 50
- high pressure gas target (70 bar)
- Second measurement with empty container necessary
- Analysis analog to ^{136}Ba

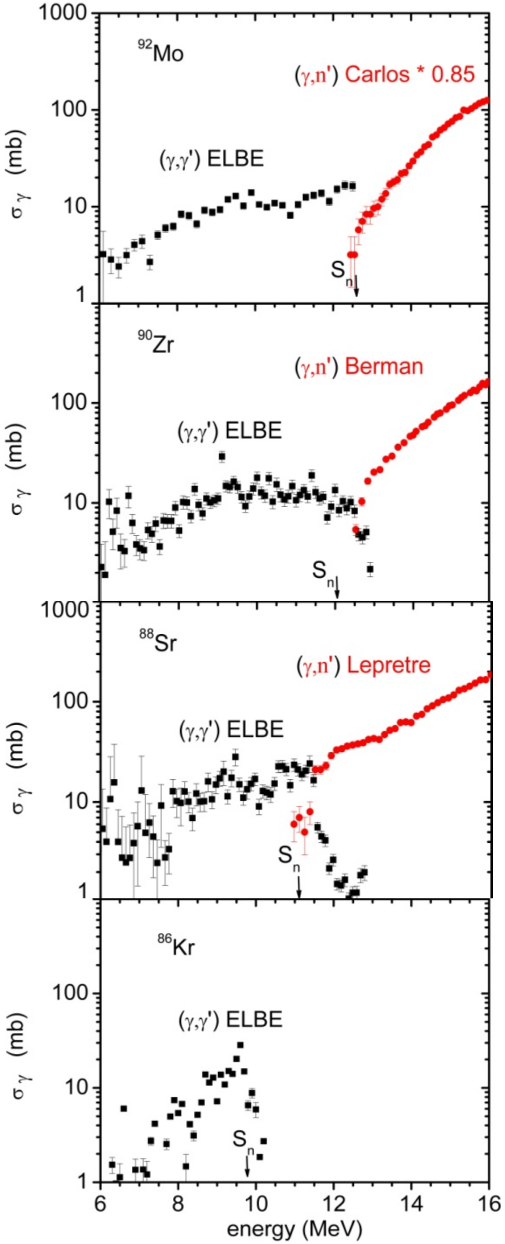




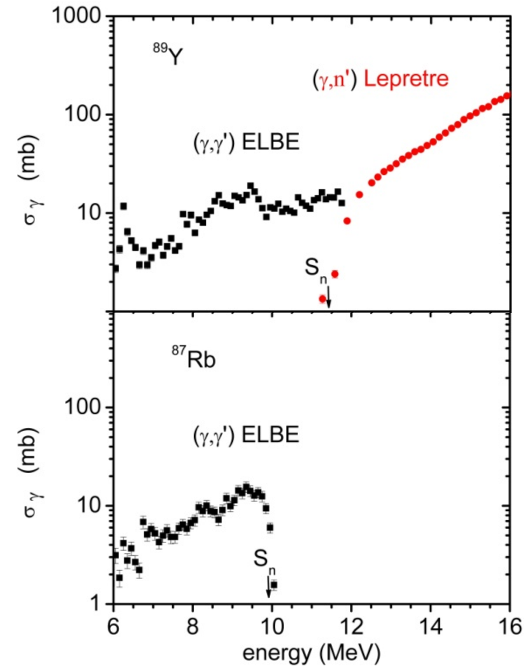
- About 34 % of dipole strength in peaks and 66 % in continuum

- Talys calculation 3 Lorentzian and M1
  (Junghans et al. PLB 670 (2008) 200) and
  (Heyde et al , ArXiv:1004.3429v2, April 2010)
- RPA calculation by F. Dönau

even – even nuclei



Enhanced strength especially pronounced in the N=50 closed-shell nuclei



odd – even nuclei

Conclusions

- Study of dipole-strength distributions at high excitation energy and high level density via photon scattering.
- Simulations with GEANT4 allow us to deduce strength from continuum
- Simulations of statistical cascades: Estimate of intensities of inelastic transitions and correction of intensities of elastic transitions
- Combination with (γ,n) data gives information over the whole energy range from low excitation energy up to the giant dipole resonance.
- Observation of extra strength in the range from 6 to 12 MeV – neither described in phenomenological approximations of dipole-strength functions nor in current microscopic models.

Thanks to all Collaborators

FZD, Institute of Radiation Physics:

D. Bemmerer, R. Beyer ,E. Birgersson, F. Dönau, E. Grosse, R. Hannaske, A. Hartmann, A. Junghans, M. Kempe, T. Kögler, A. Matic, K.-D. Schilling, G. Schramm, R. Schwengner, A. Wagner

TUNL Durham:

G. Rusev, A. Tonchev