X-ray pump-probe experiments with nuclei

Adriana Pálffy

Max Planck Institute for Nuclear Physics, Heidelberg, Germany

SLAC NATIONAL ACCELERATOR LABORATORY

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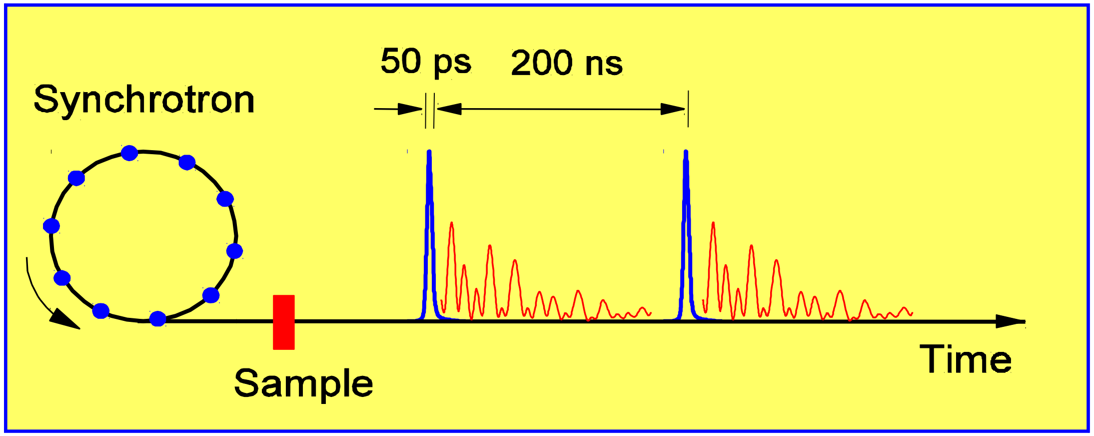
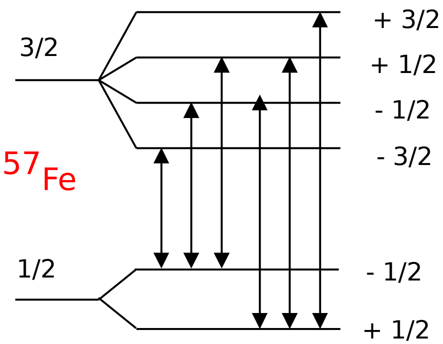
Previous experiences ...

• scaling in brilliance from synchrotrons + nuclei





@ 14.413 keV

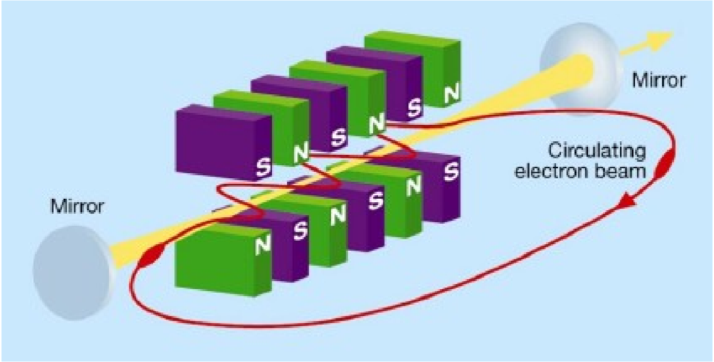
Nuclear Forward Scattering (NFS) of Synchrotron Radiation

nuclear condensed matter physics based on the Mössbauer effect,
*control of nuclear decay for ensembles of nuclei**, *storing single x-ray photons*

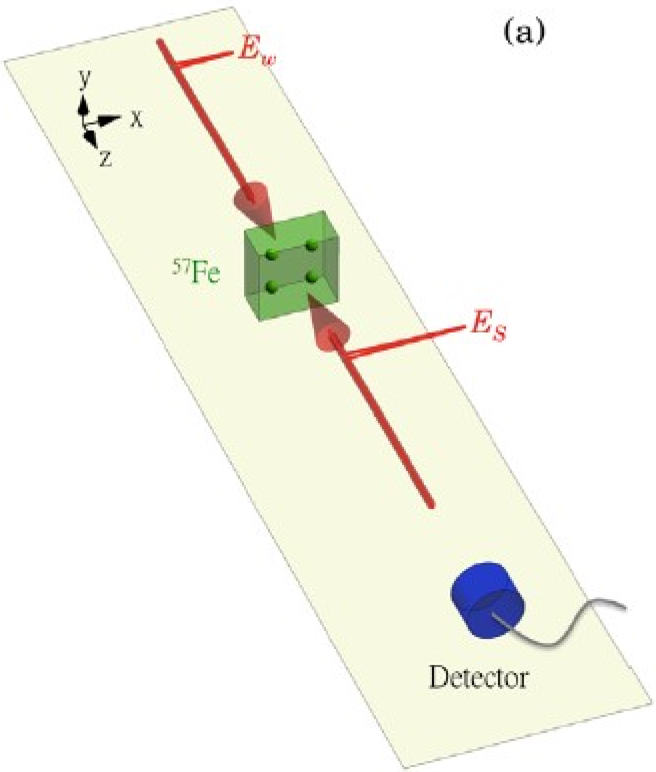
* relies on weak excitation, a single nucleus only!

WHAT HAPPENS WHEN THE XFELO COMES INTO PLAY?
…today in the Mössbauer session.

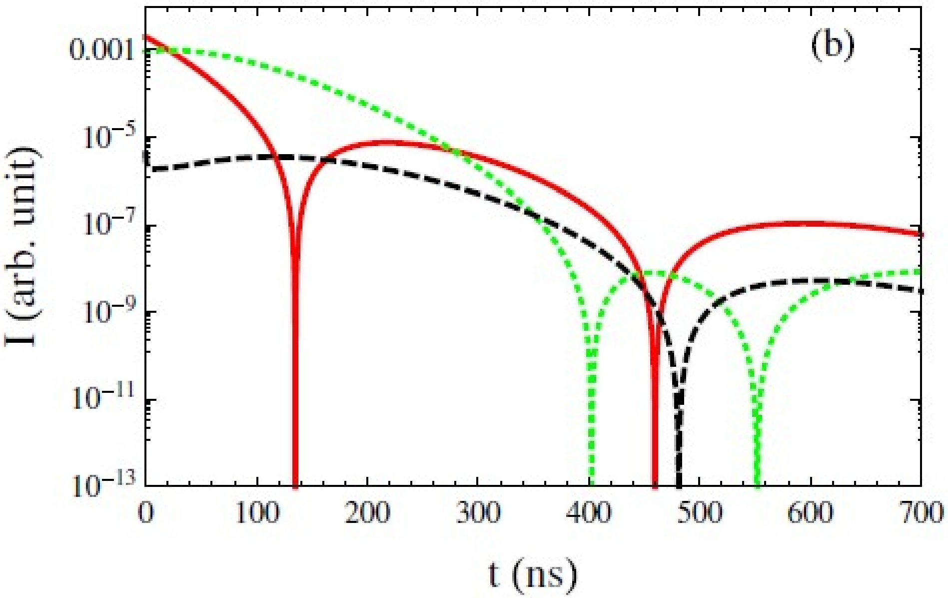
Pump-probe experiments



use XFELO photoexcitation as pump
“strong pulse”



single transition (no hyperfine splitting)



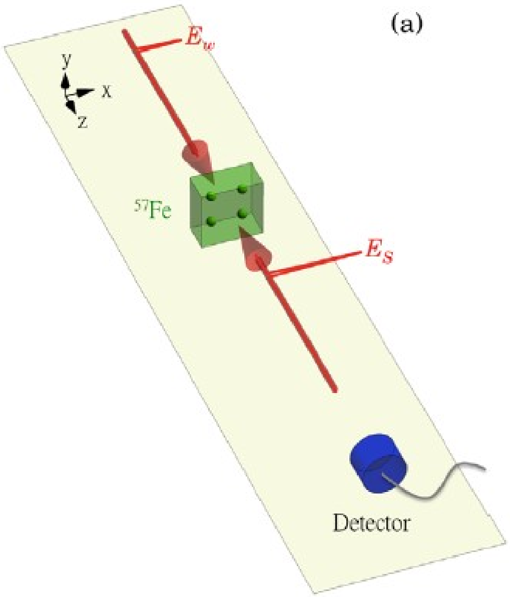
no S

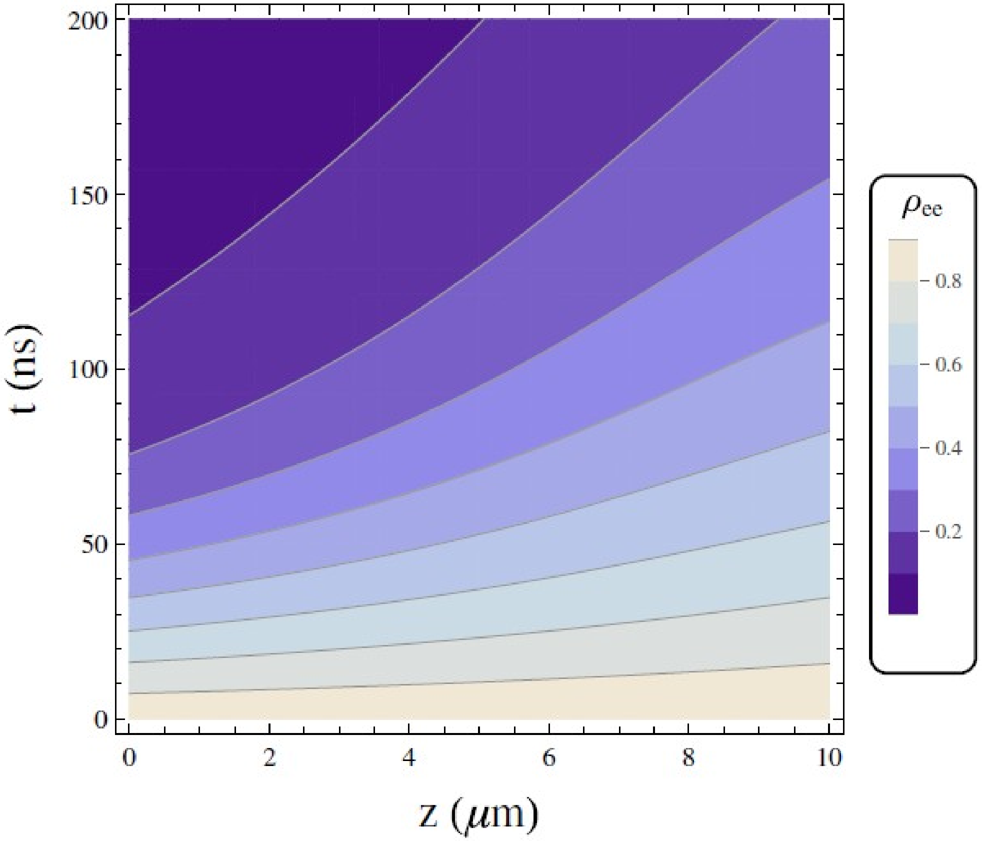
S 10 ns

S 50 ns

X. Kong, W.-T. Liao and AP, New J. Phys. 16, 013049 (2014)

Pump-probe experiments





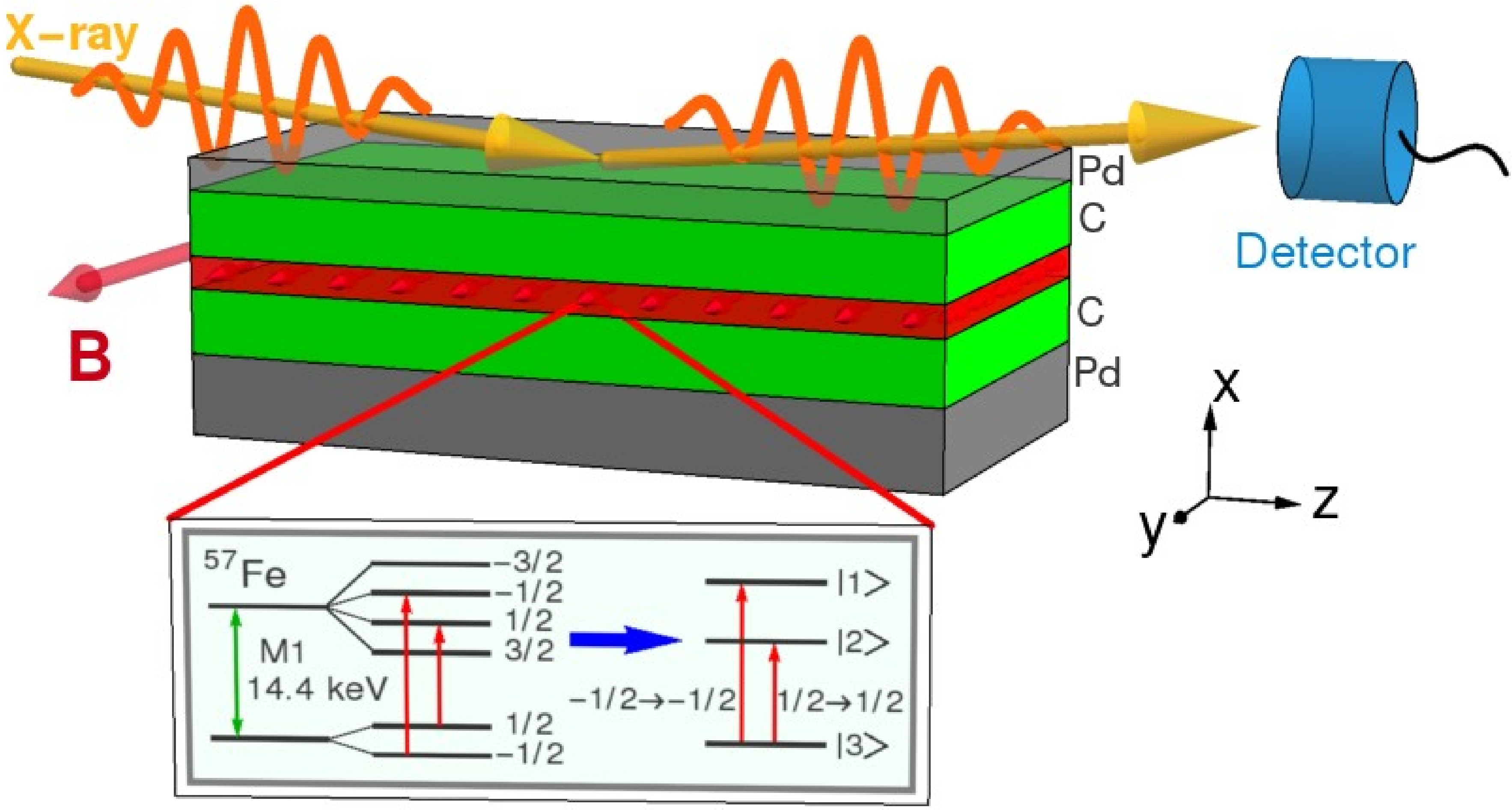
$$\vec{E}(z,t) = E_{\rm w}(z,t)e^{-{\rm i}(\omega t - k_0 z)}\vec{e}_x + E_{\rm s}(z,t)e^{-{\rm i}[\omega t - k_0(L-z)]}\vec{e}_x$$

$$\rho_{eg}(z,t) = \rho_{eg{\rm w}}(z,t)\, e^{-{\rm i}(\omega t - k_0 z)} + \rho_{eg{\rm s}}(z,t)\, e^{-{\rm i}[\omega t - k_0(L-z)]}$$

$$\partial_t \rho_{eg{\rm w}} = -\left({\rm i}\Delta + \frac{\Gamma}{2}\right)\rho_{eg{\rm w}} - \frac{\rm i}{2}\Omega_{\rm w}(\rho_{ee} - \rho_{gg})$$

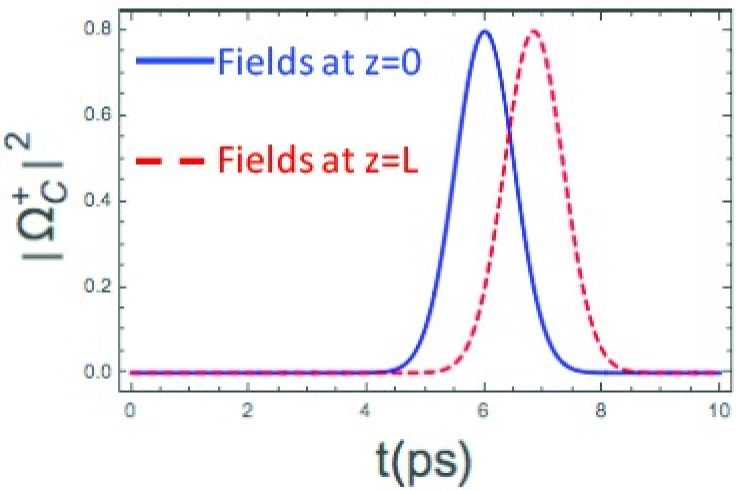
X. Kong, W.-T. Liao and AP, New J. Phys. 16, 013049 (2014)

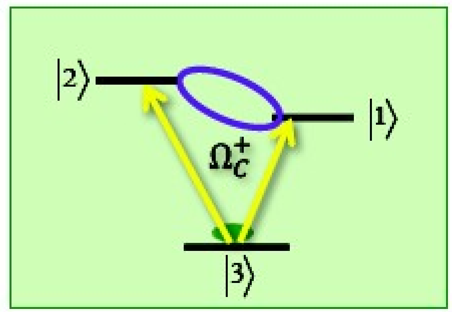
Using thin-film cavities

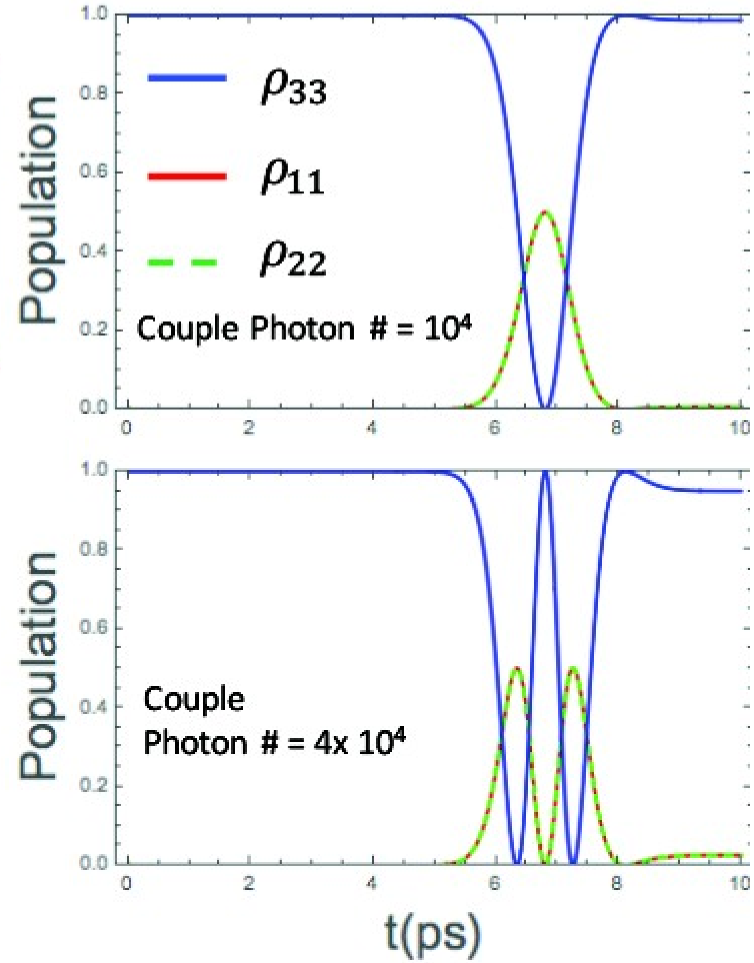


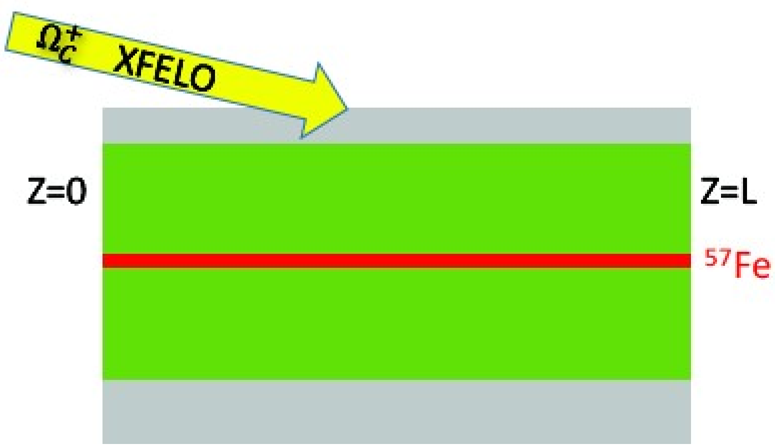
Strong driving of few nuclei (Wen-Te Liao)

Nuclear Rabi Oscillation









$g\sqrt{N} = \sqrt{6.3\times10^6}$

$\gamma' = 19.4\,\gamma$

$\gamma = 7.1\ MHz$

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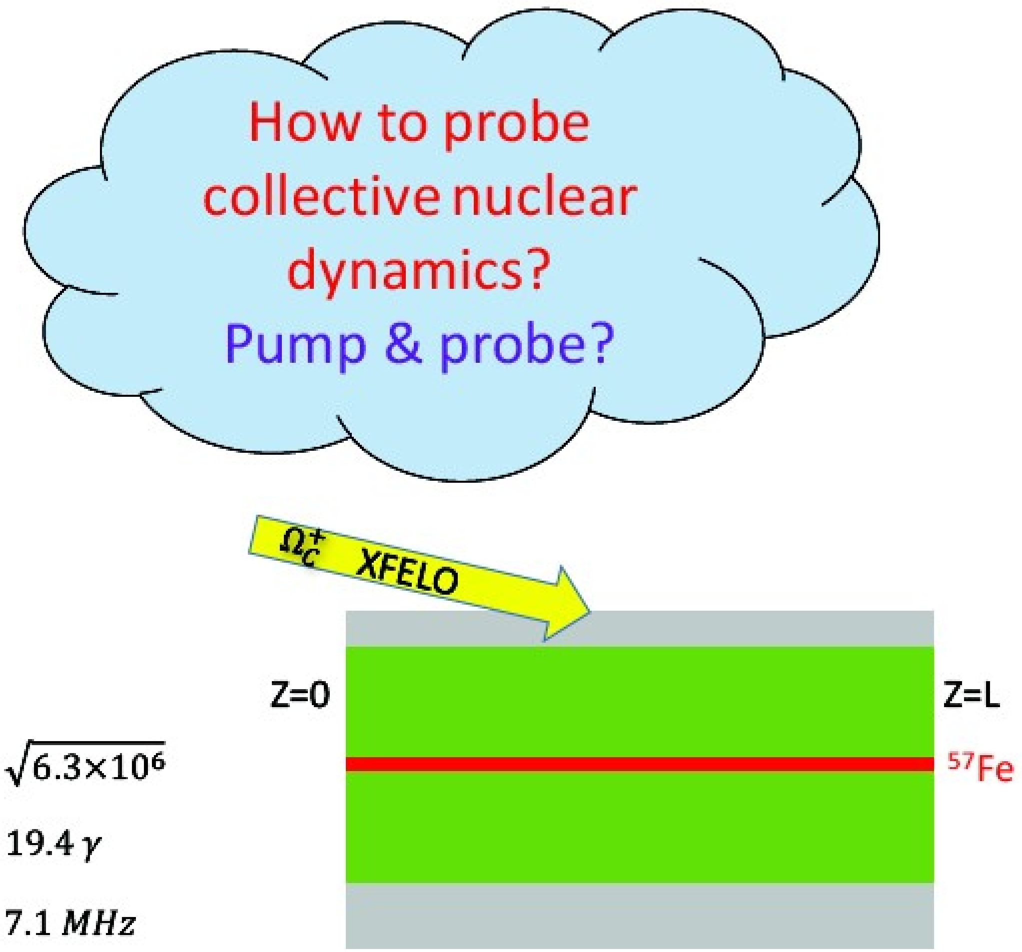

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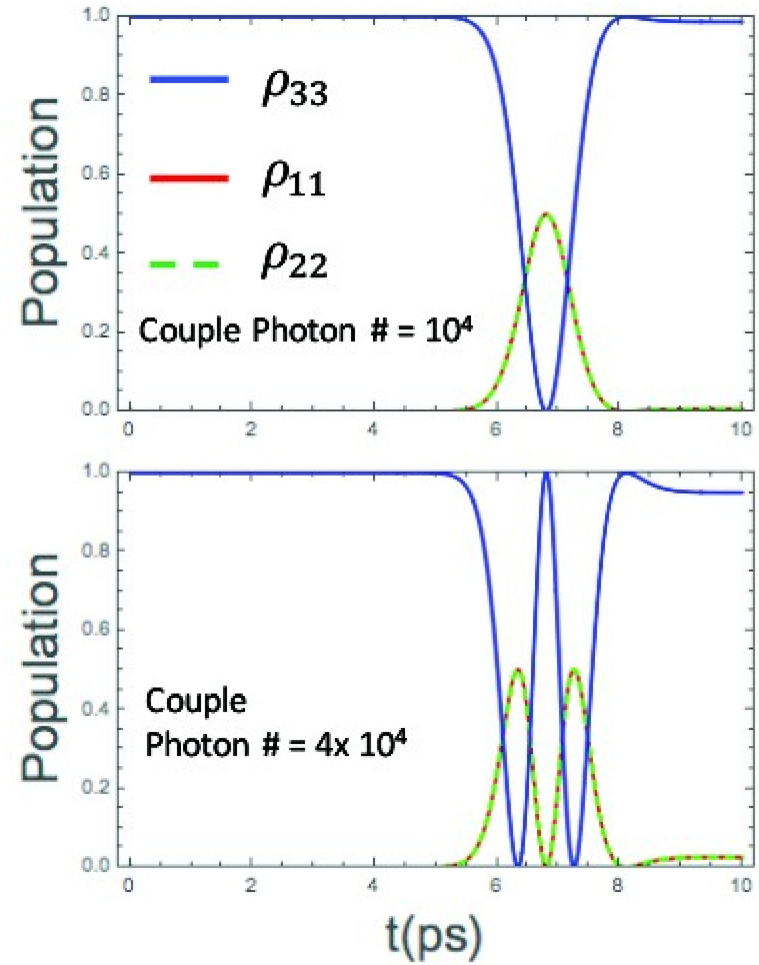
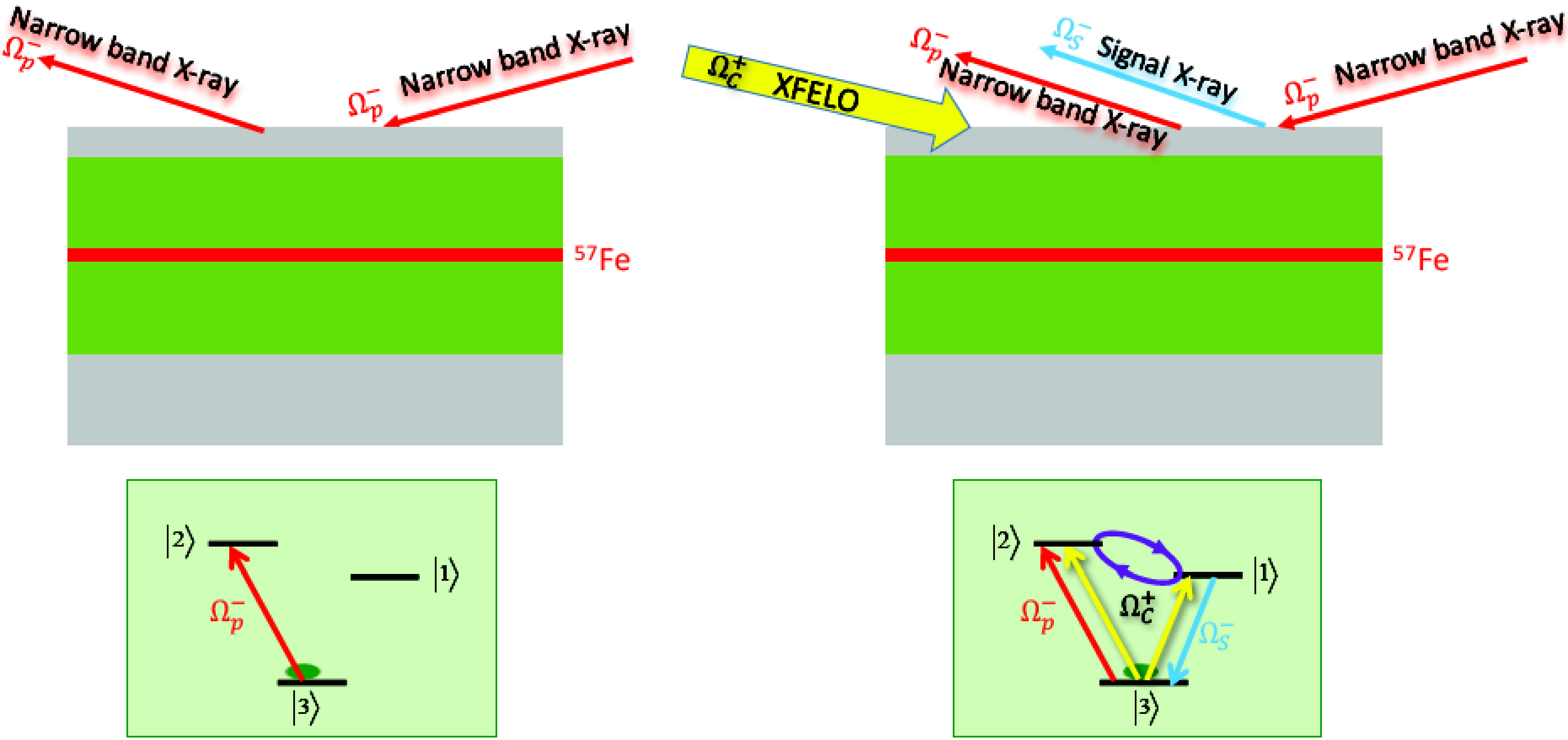


Counter-propagating pulses in cavities (Wen-Te Liao)

Nuclear Four-Wave Mixing using XFELO



Case 1 without XFELO

Case 2 with counter-propagating XFELO

Counter-propagating pulses in cavities (Wen-Te Liao)

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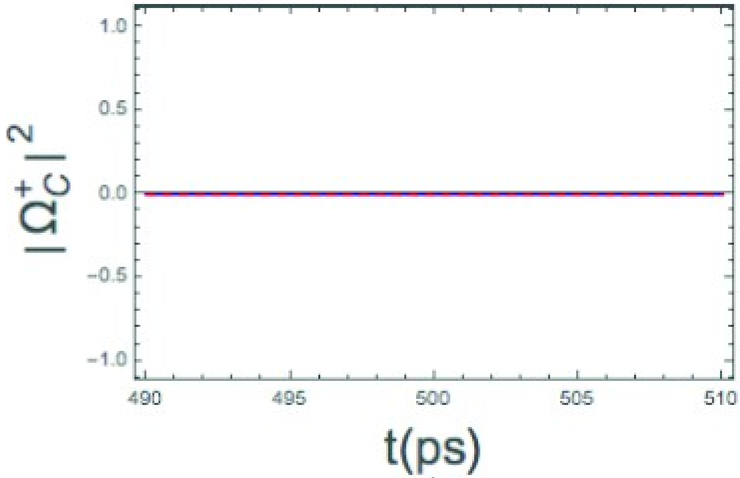
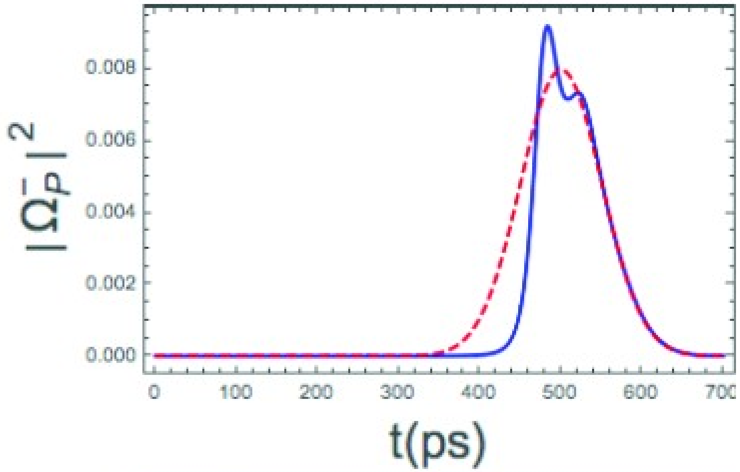
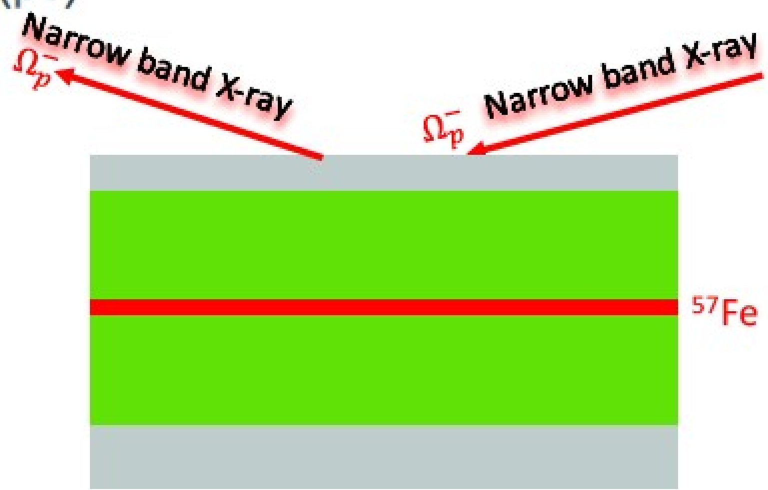






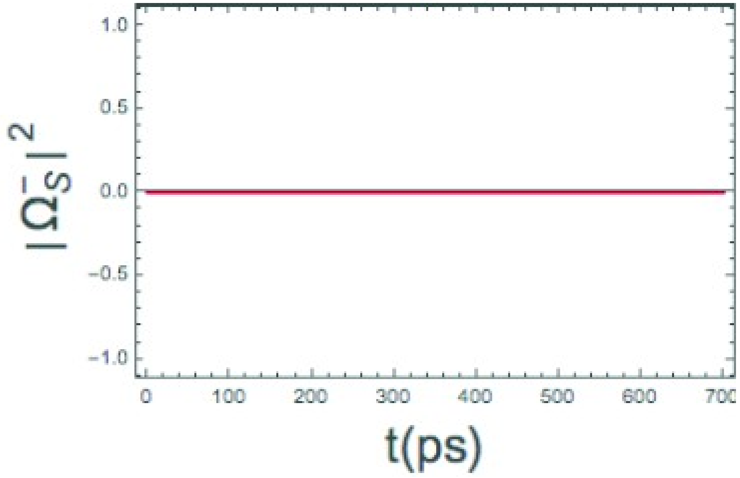
Photon # of couple = 0

Photon # of probe = 2.5

$g\sqrt{N} = \sqrt{6.3\times10^9}$

$\gamma' = 1.84\times10^4\gamma$

$\gamma = 7.1\ MHz$



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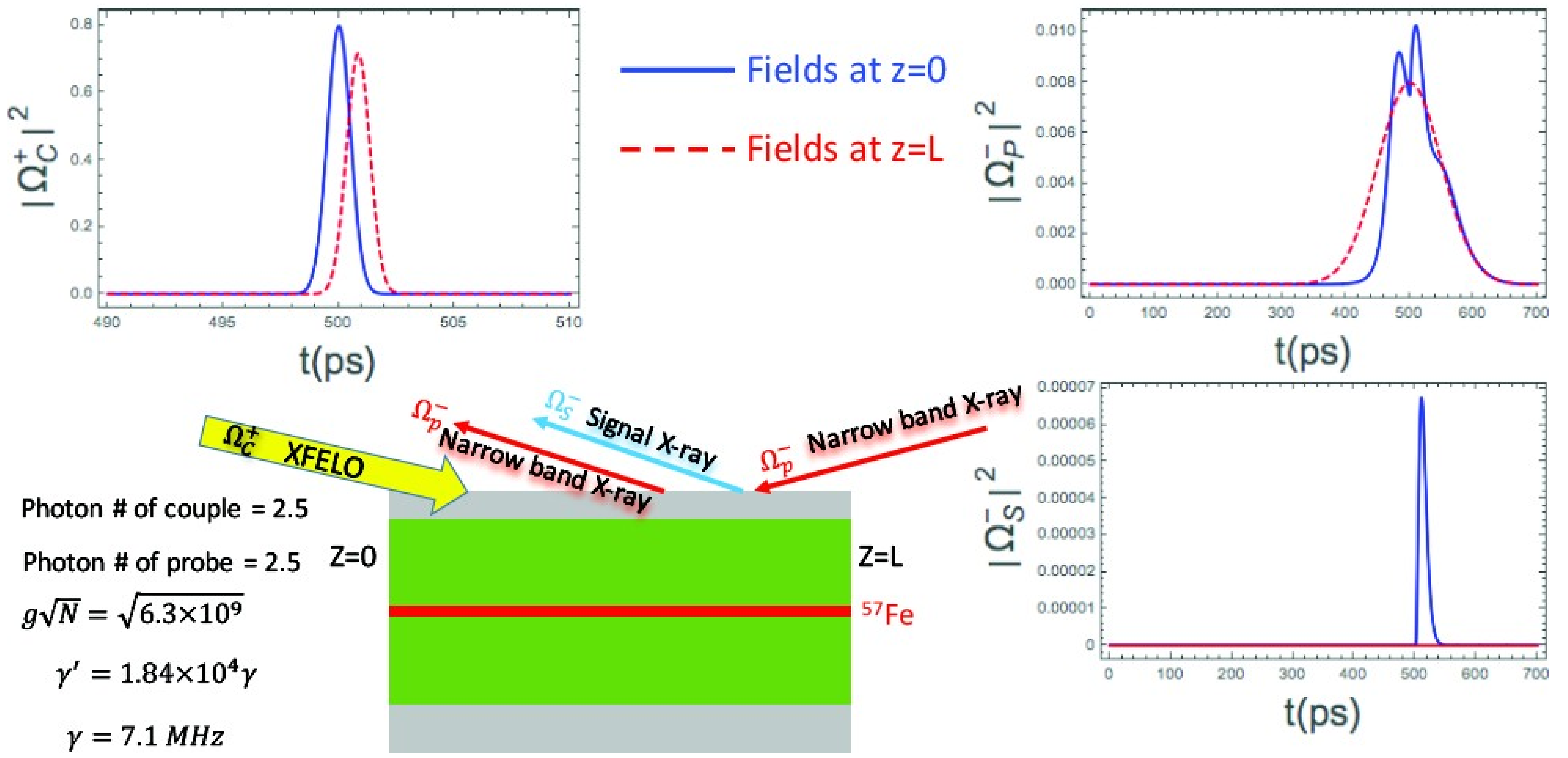

Summary & Requirements

Driving nuclear transitions...

can be done much more efficiently with XFELO

Possible applications borrowed from atomic systems...

pump-probe experiments, Rabi oscillations, 4-wave mixing

Closer to nuclear physics...

exploit efficiency of XFELO to probe for the first time nuclear reactions starting from excited nuclear states

Needed:
most importantly, tunability for addressing nuclear resonances!
Intensity, repetition rate, BW depending on the envisaged application
Average vs. peak brilliance an issue depending on whether excitation after one pulse or excitation after 1 s is of interest.

Thank you for your attention!