Tempus Fugit: an Italian time-focusing spectrometer for ESS

Andrea Orecchini

Dipartimento di Fisica, Università di Perugia, Italy

Contributions from:

University of Perugia

University of Roma 3

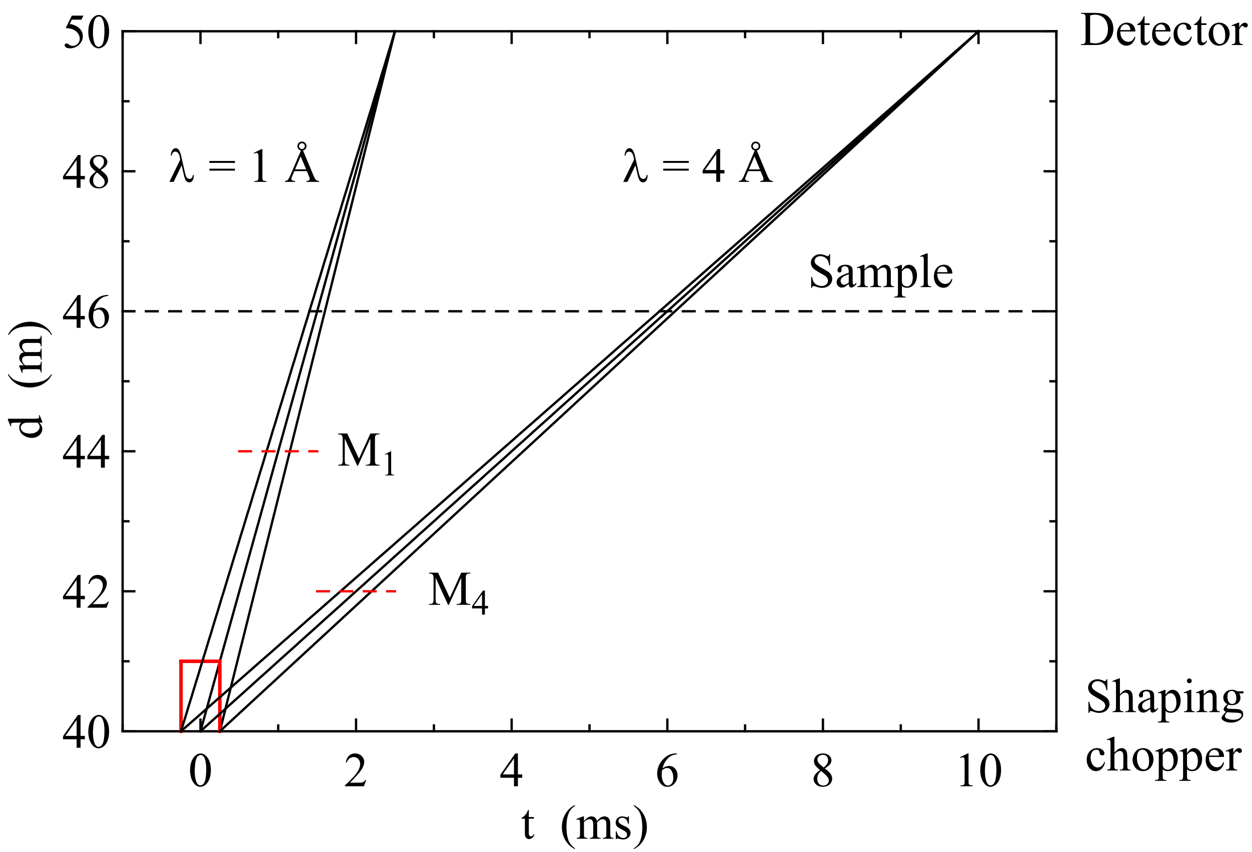
Sincrotrone Trieste

University of Roma La Sapienza

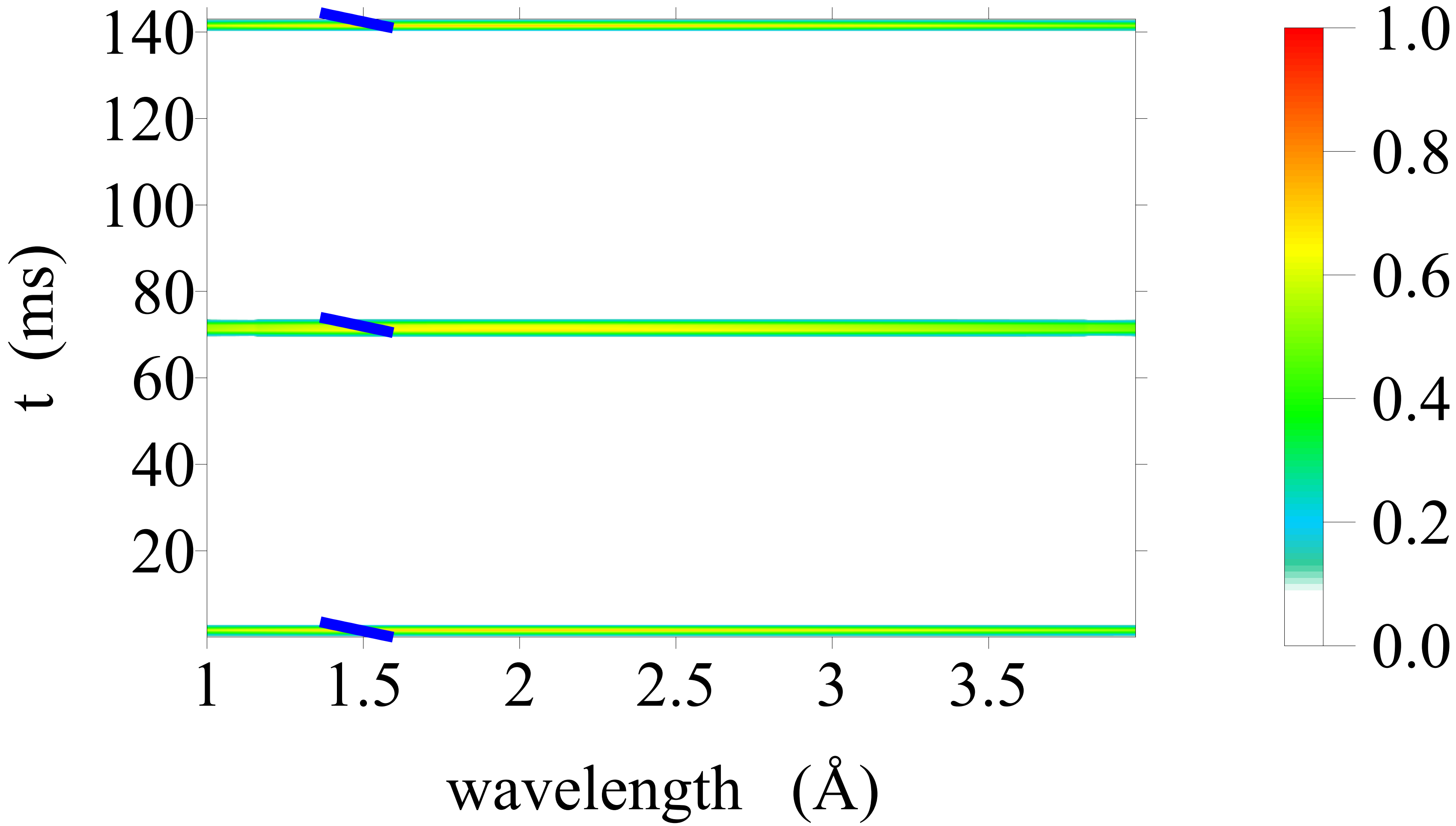
University of Florence

IOM-CNR, c/o ILL Grenoble

Principle of operation of the time focusing at ESS

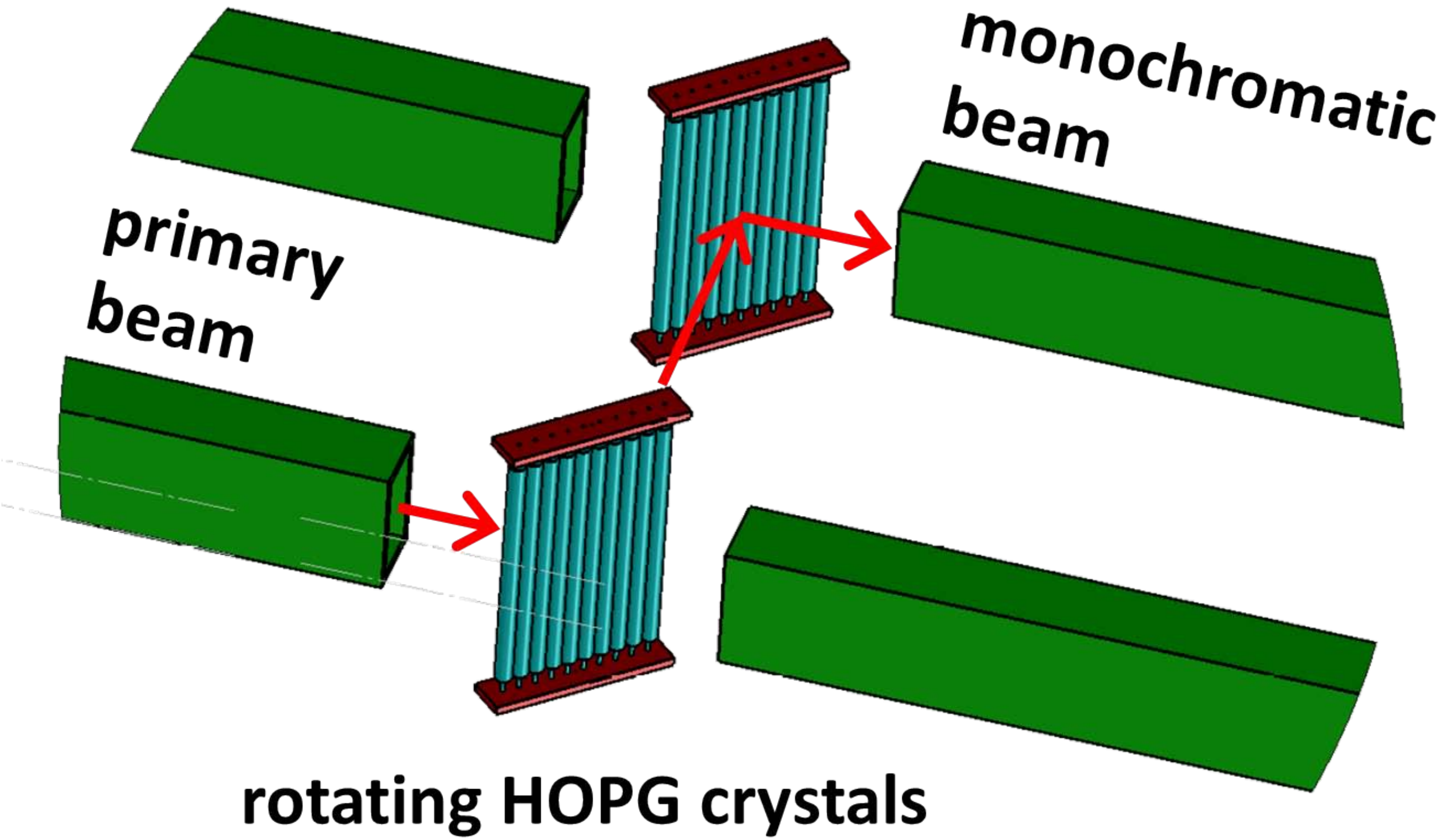


Two wavelengths are sketched in the (*t*,*d*) plot assuming the same monochromator time to put them on the same plot. The actual starting time is 10 ms and 40 ms respectively.

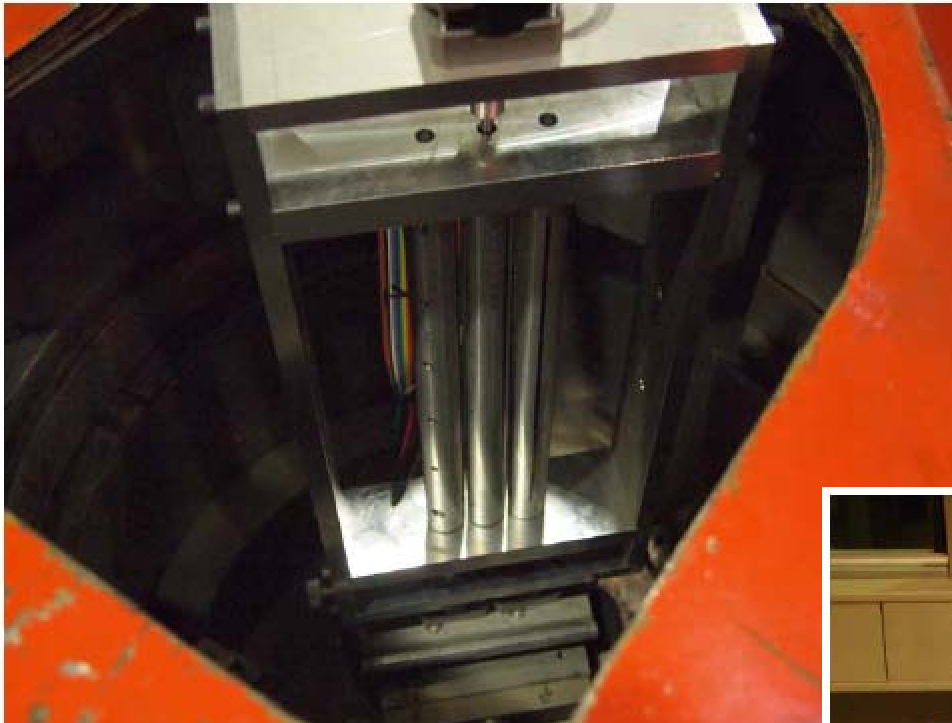


Time cut of the source pulse

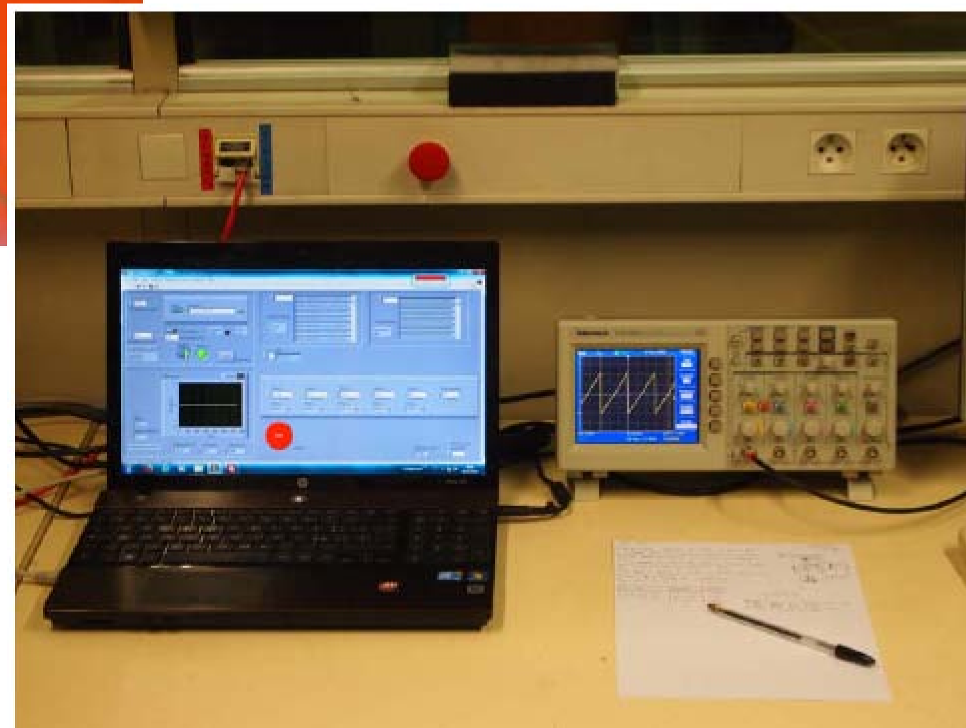
A Double Rotating-Crystal Monochromator



The prototype



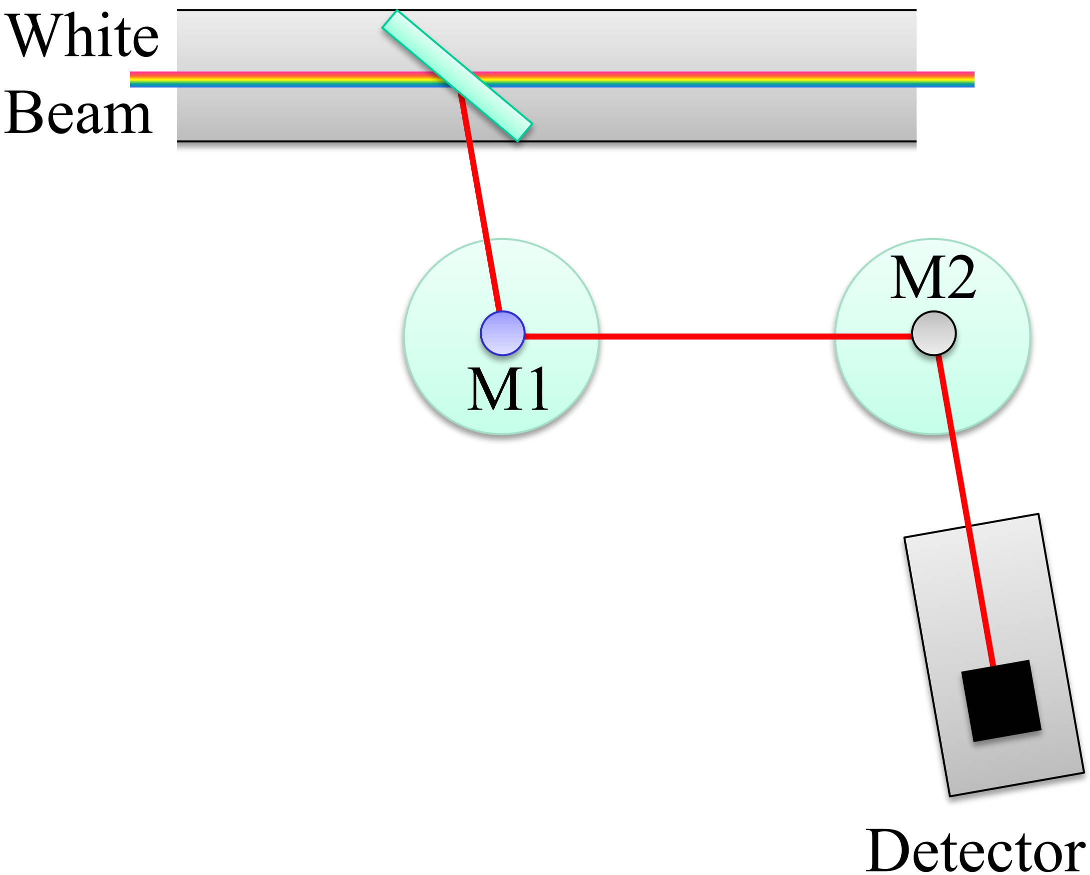
Test monochromator with three elements



Control station for both monochromator rotation and *single-event* acquisition

Test ToF measurements

Test beamline IN3@ILL (Grenoble, France)



IN3 monochromator (PG 002)

$\lambda_1 = 4.26$ Å

$\lambda_2 = 2.13$ Å

$\lambda_3 = 1.42$ Å

$\lambda_4 = 1.07$ Å

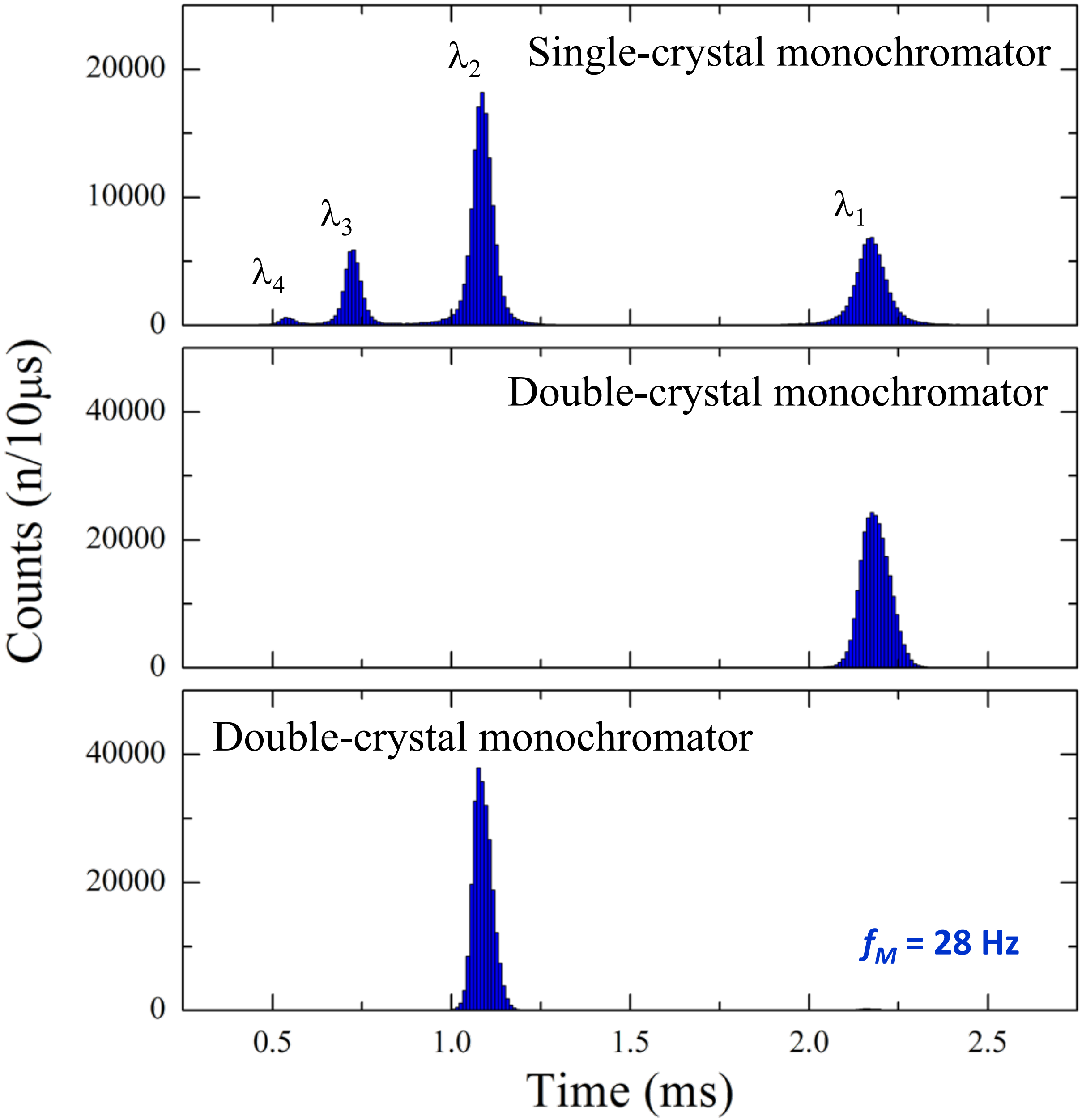
M1 – 1st monochromator

1 cylinder at IN3 sample position

M2 – 2st monochromator

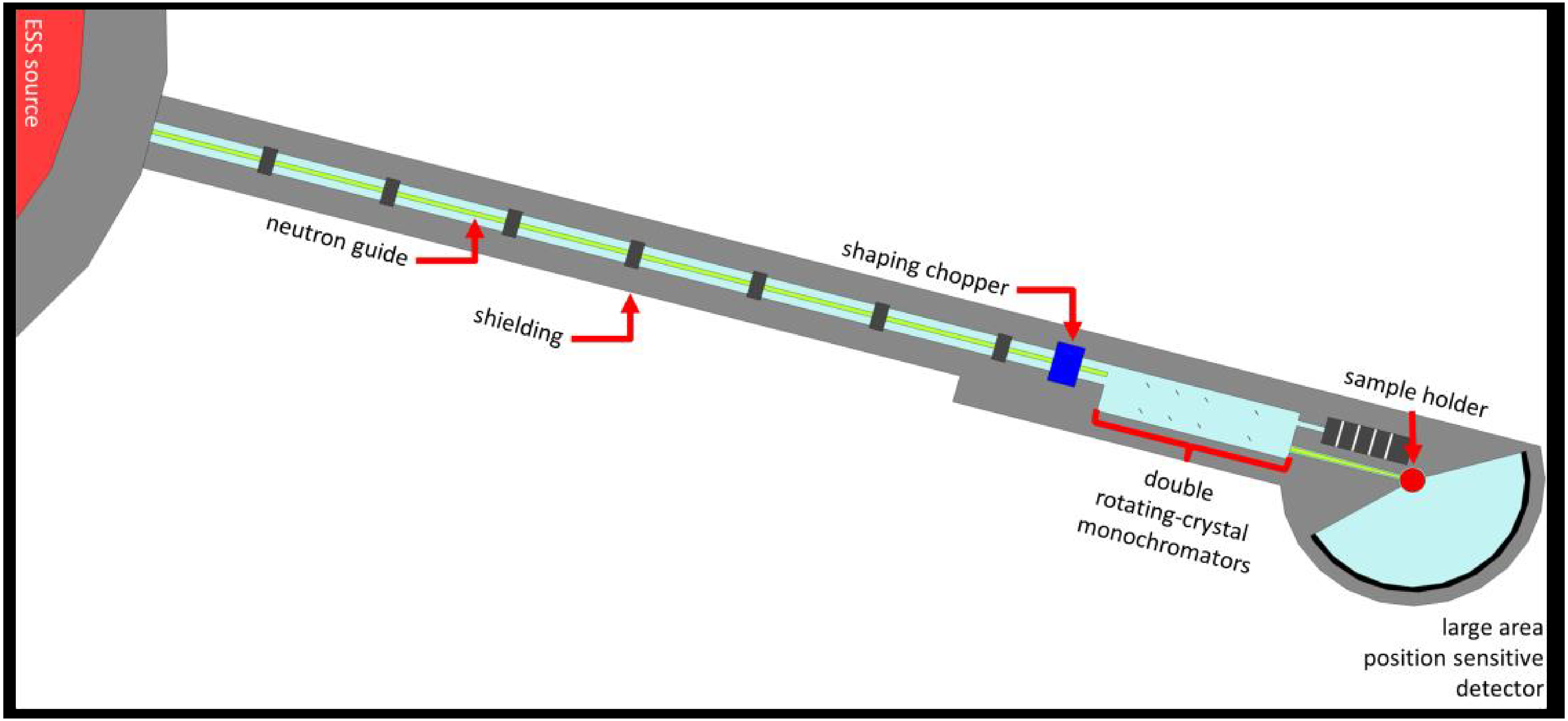
3 cylinders at IN3 analyser position

Test ToF measurements with <u>*single-event*</u> acquisition system.



Correct phasing of the two monochromators allows for the selection a chosen Bragg order.

Instrument design from the source to the detector



Major components:

Primary converging guide 30 m

Shaping chopper, thick T_0 chopper

Rotating monochromators, 4 to 6 devices for repetition rate multiplication

Sample beam shifted from the primary beam for low background

Intensity estimate at the sample position in the case of TF and in the case of a Chopper instrument of similar characteristics

$$I_S^{tf} = \Phi_{(o)}^{tf}(\lambda_1)\, f_r\, S_M\, R_X^2\, T_G\, \Delta\Omega_s\, \underline{\underline{T}}\Delta E$$

$$I_S^{C} = \Phi_{o}^{C}(\lambda_1)\, f_r\, S_C\, T_C\, T_G\, \Delta\Omega_s\, \underline{\underline{\Delta t}}\Delta E$$

Where:

Δt = chopper opening time

T = pulse length

An intensity estimate with some possible numerical values…

$$\Phi_o^{tf}(\lambda_1) = \Phi_o^{C}(\lambda_1) = 3 \times 10^{11}\ \text{n/cm}^2\ \text{s sterad meV}$$

$S_M = 50\ \text{cm}^2$ $\quad S_C = 10\ \text{cm}^2$ $\quad \dfrac{\Delta t}{T} < 0.1$

Inverse time-focusing gain can be as small as 0.025

$R_X^2 = 0.49$ $\quad T_G = T_C = 1$

$\Delta\Omega_s\ \text{TF} = 2\cdot 10^{-4}$ $\quad \Delta\Omega_s\ \text{C} = 4\cdot 10^{-4}$

$I_S^{tf} = 1.6\ 10^8\ \text{n/s} \approx 3.4\ 10^6\ \text{n/ cm}^2\ \text{s}$ (IN4@ILL: $5\cdot 10^5$ n/ cm^2 s)

$I_S^{C} = 0.4\ 10^7\ \text{n/s} \approx 1.5\ 10^6\ \text{n/ cm}^2\ \text{s}$ with $\dfrac{\Delta t}{T} = 0.1$

assuming perfect guides and minimum time-focusing gain

Analytic study of the energy resolution function

$$W_E = \sqrt{{W_{Etf}}^2 + 4\Big[\Big(1 - \frac{\epsilon}{E_1}\Big)\epsilon\frac{\omega_M T}{\tan\theta_M}\Big]^2}$$

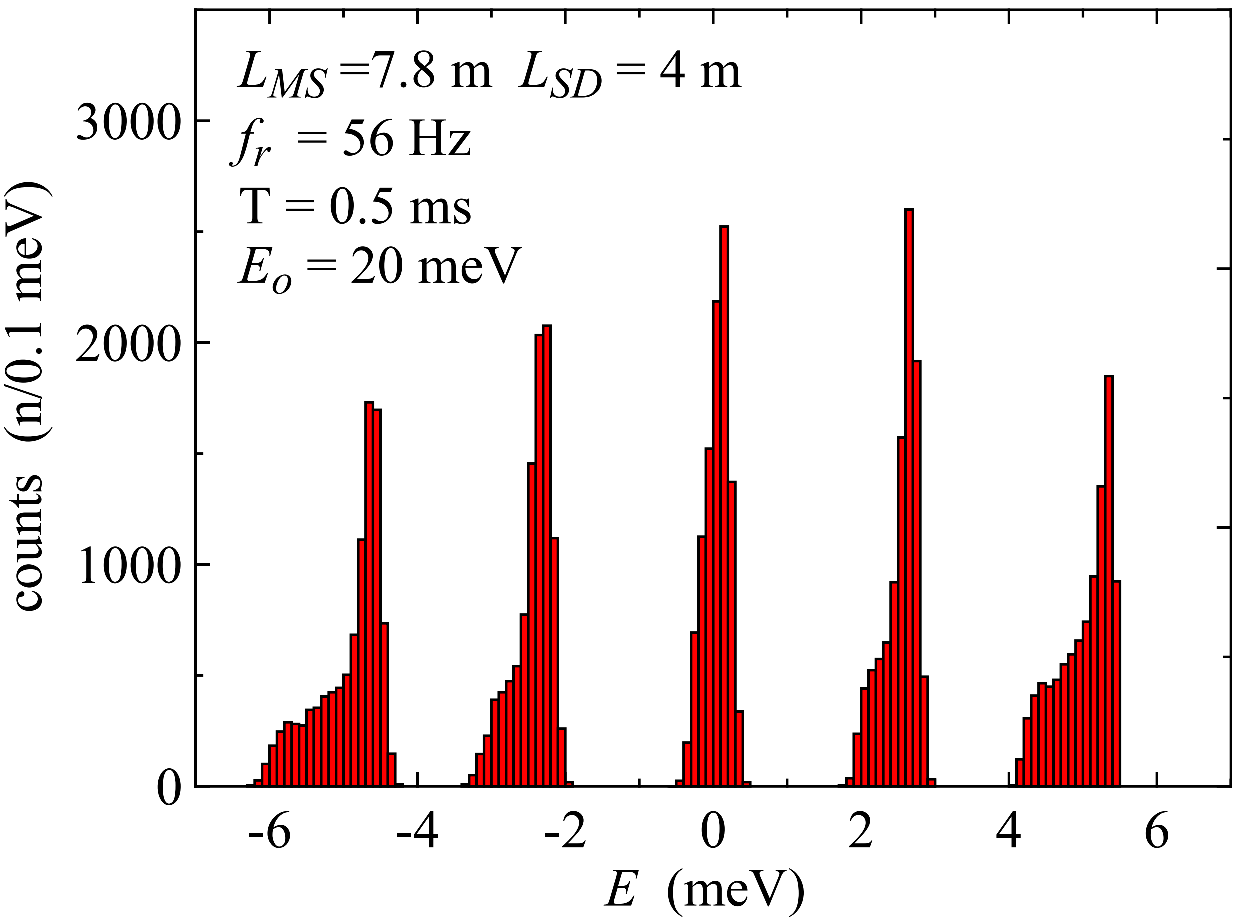
$$W_{Etf} = \sqrt{W_1^2 + W_2^2}$$

$$W_1^2 = \Big\{\frac{\sqrt{2}\,\eta_M}{\tan\theta_M}\Big[E_1\Big(\frac{L_{MS}}{L_{SD}} + 1\Big) - \frac{3}{2}\epsilon\frac{L_{MS}}{L_{SD}}\Big]\Big\}^2$$

$$W_2^2 = 4(E_1 - \epsilon)^2\left[\Big(\frac{l_D}{L_{SD}}\Big)^2 + \frac{E_1 - \epsilon}{M_n}\Big(\frac{\eta_M}{\omega_M L_{SD}}\Big)^2\right]$$

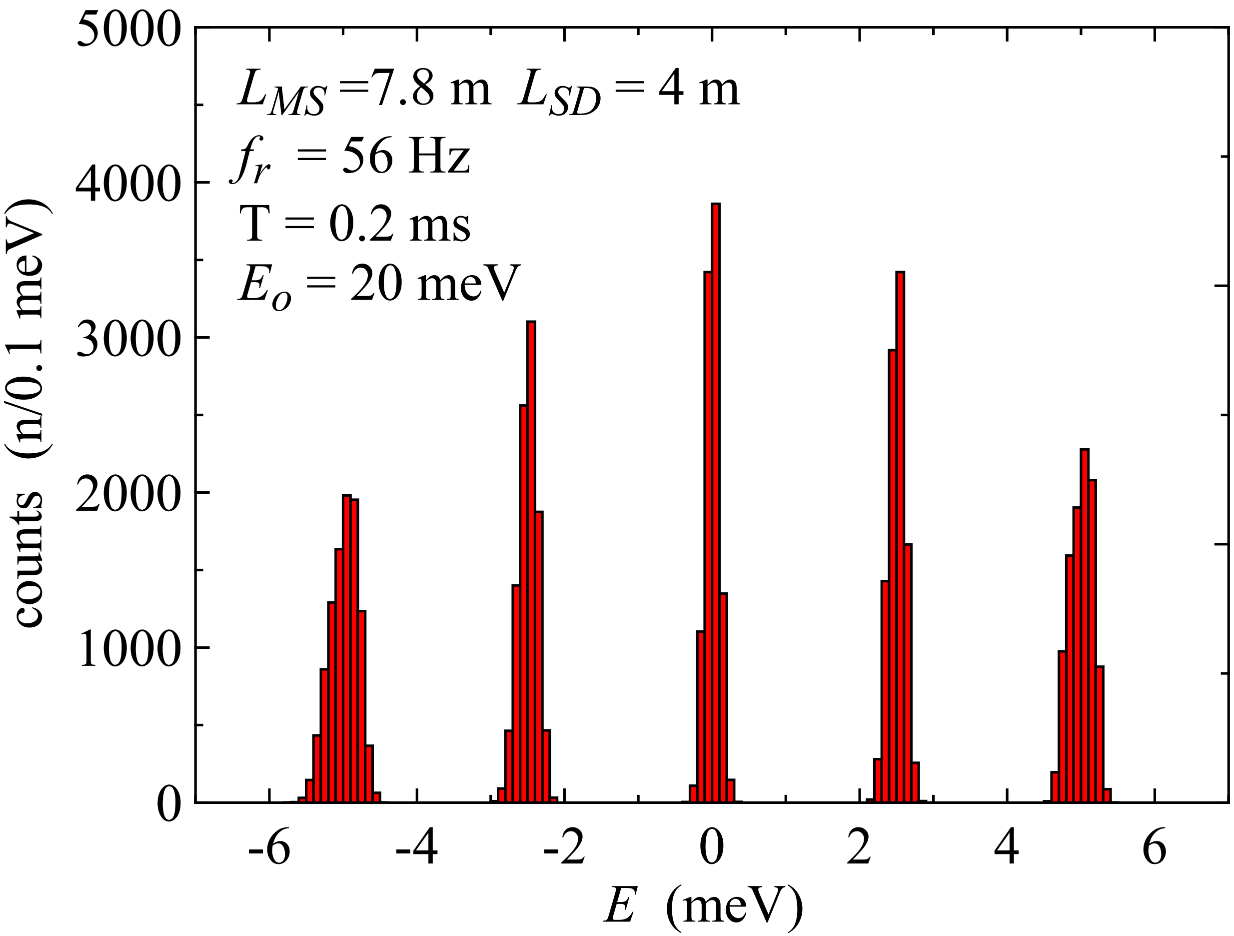
Simulated resolution function versus energy transfer at thermal energy (incoming energy 20 meV)

$$\frac{\Delta t}{T} = 0.03$$

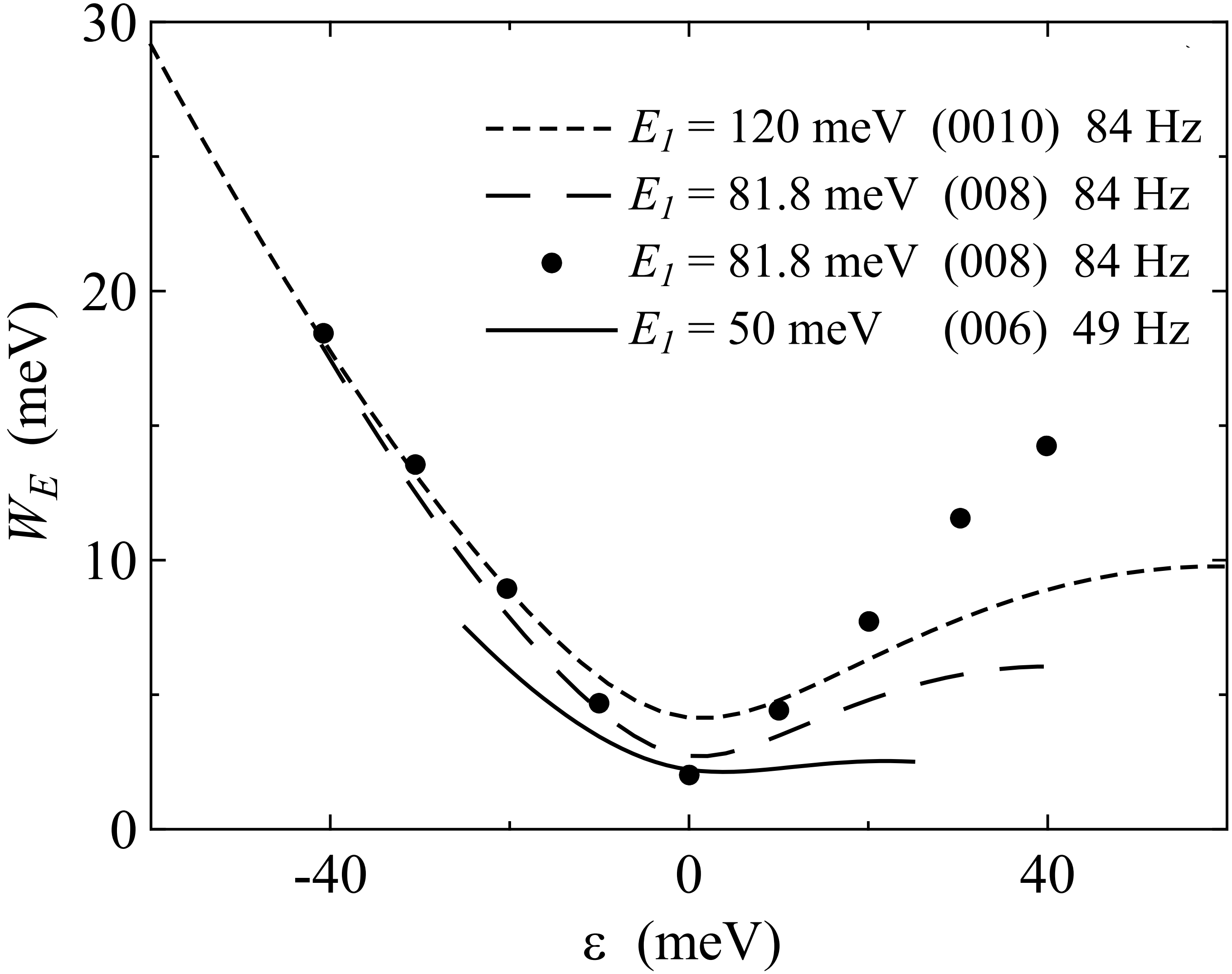


On decreasing the time window the resultion function improves but the intensity decreases *linearly* with the energy resolution

$$\frac{\Delta t}{T} = 0.075$$



FWHM of energy resolution in different conditions from simulation (lines) and from the analytic formulation (dots)



Conclusion

The feasibility of a large area monochromator is demonstrated for what concerns the mechanics, therefore the possibility of time focusing can be an option for ESS in the near thermal range (3-100 meV). A CDR is being completed to be submitted to ESS.

Future Steps

Complete design, including up to six monochromators to use repetition rate multiplication, is planned this year.

Full McStas simulations of the whole instrument are being developed.

A discussion workshop on the scientific case of the instrument will take place next week.


New science from time-focusing neutron scattering spectroscopy at the ESS
Elettra Sincrotrone Trieste
Breaking science in:
New Materials for Pharmaceutics and Food Technology
New Materials for Energy and Nanotechnology
Biology, Biotechnology and Theranostics
Magnetism and Superconductivity
Taormina
3-4 october 2013
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