Monte Carlo simulations for the development of polarised neutron instrumentation

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Contributions

VITESS programmer colleagues over the years:
Klaus Lieutenant, Sergey Manoshin, Michael Fromme, Dietmar Wechsler, Friedrich Streffer, John Stride

UCN Group at PSI:
Manfred Daum, Klaus Kirch, Axel Pichlmaier, Reinhold Henneck, Francis Atchison, Peter Fierlinger

Outline

- The VITESS MC simulation package - Polarisation
- New ultra cold neutron (UCN) optics components
- Effectiveness of using ‘virtual experiments’ – an example:

  MC data evaluation of the Fermi potential
- Outlook

The VITESS MC simulation package
Polarisation

Polarisation since mid 2001 starting V2.0

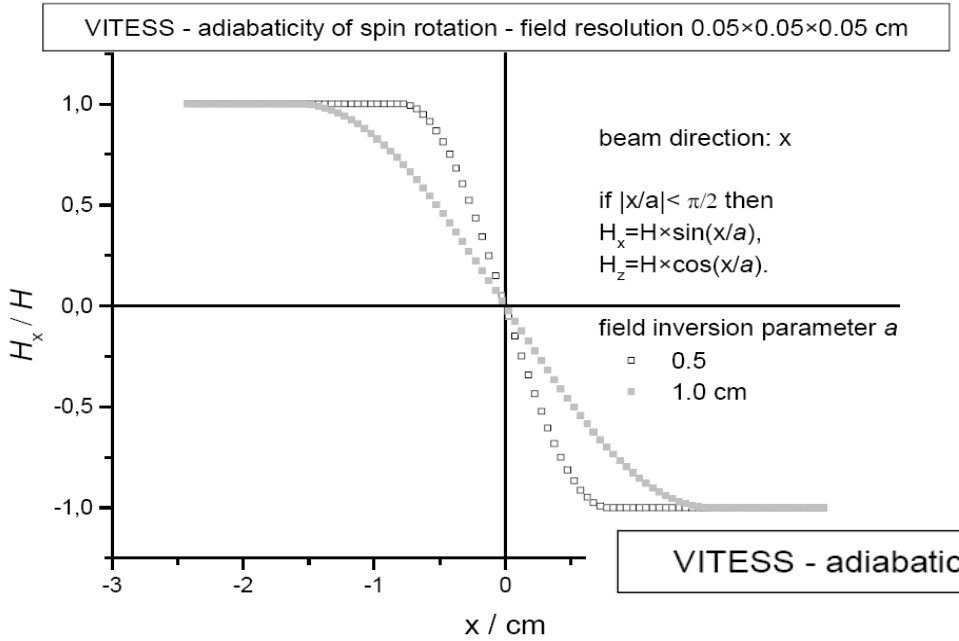
Polarised modules

Supermirror polariser
Polarising mirror
^{3}He polariser
Polarising bender
Supermirror ensemble

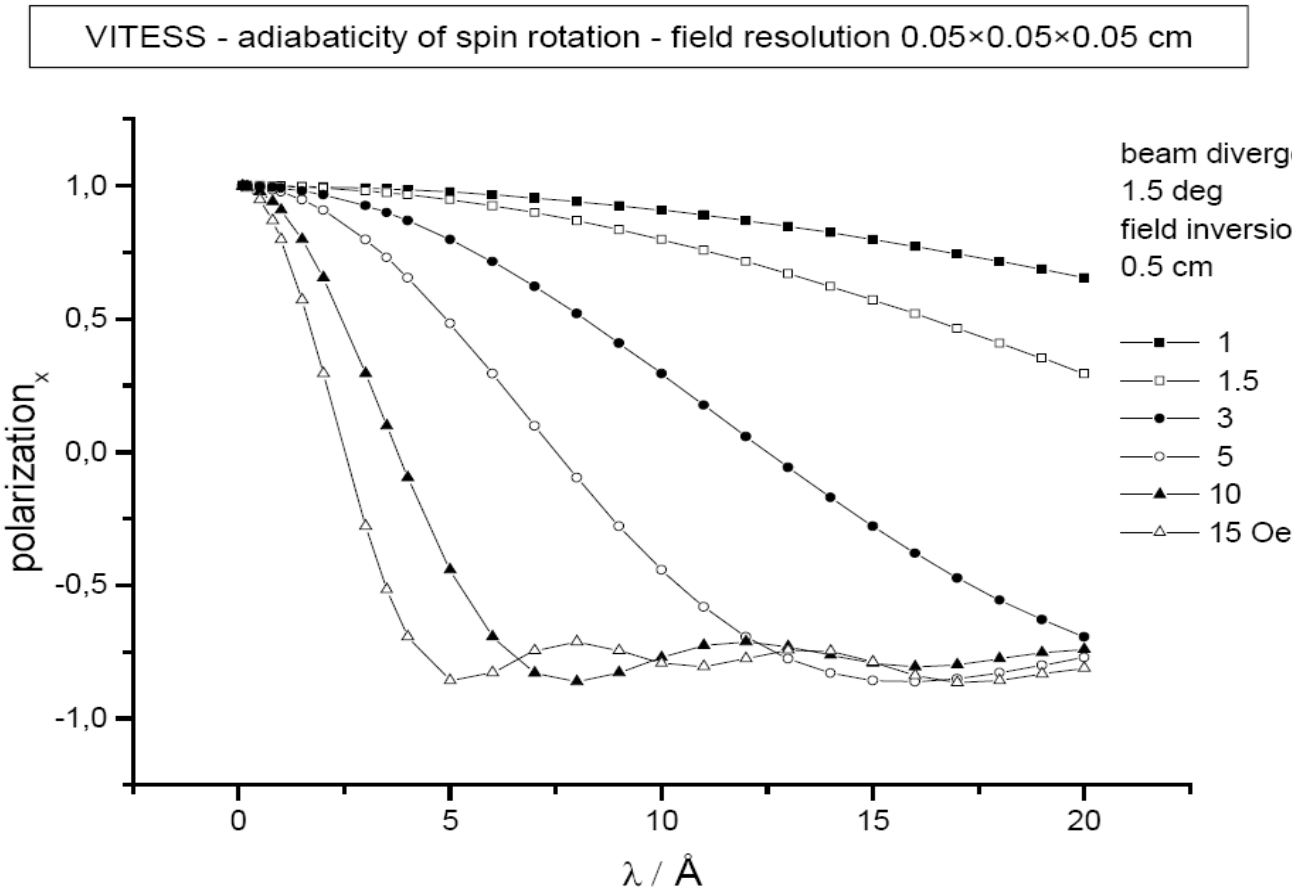
Coil flipper
Gradient flipper
Precession field
Rotating field
Drabkin resonator

Polarisation monitors

New features, extensions to come



Adiabaticity of spin rotation



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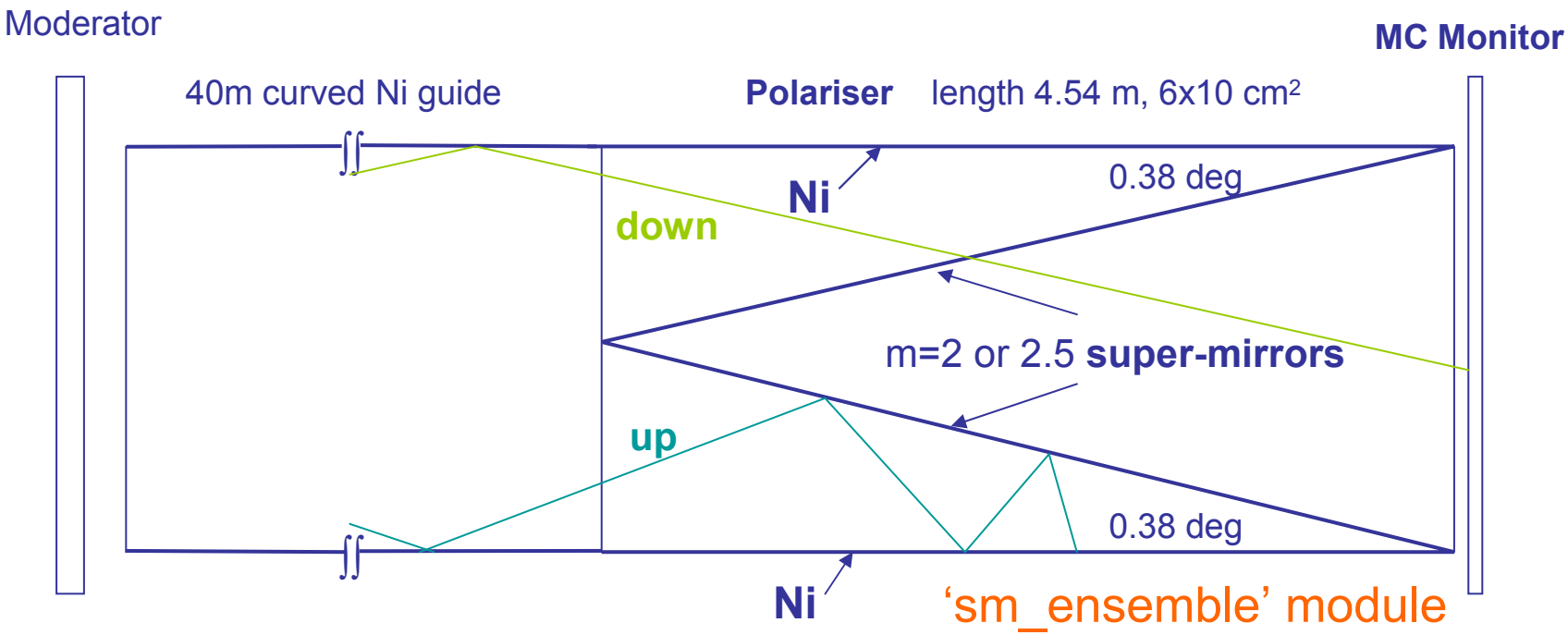
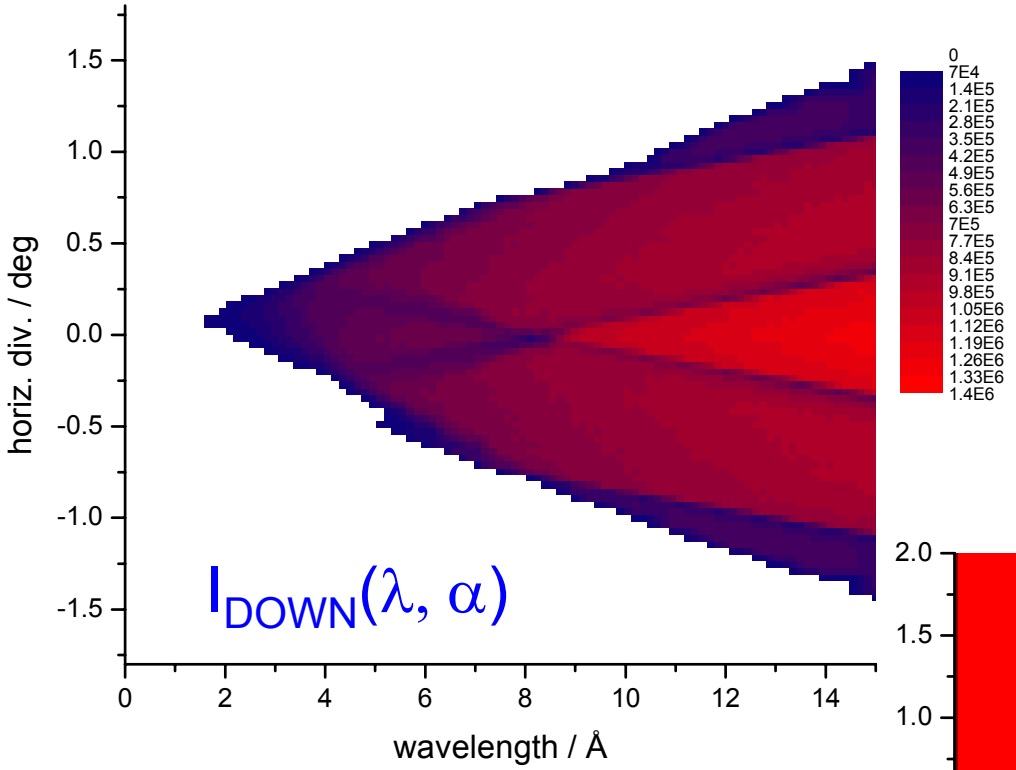
Supermirror polarising cavity



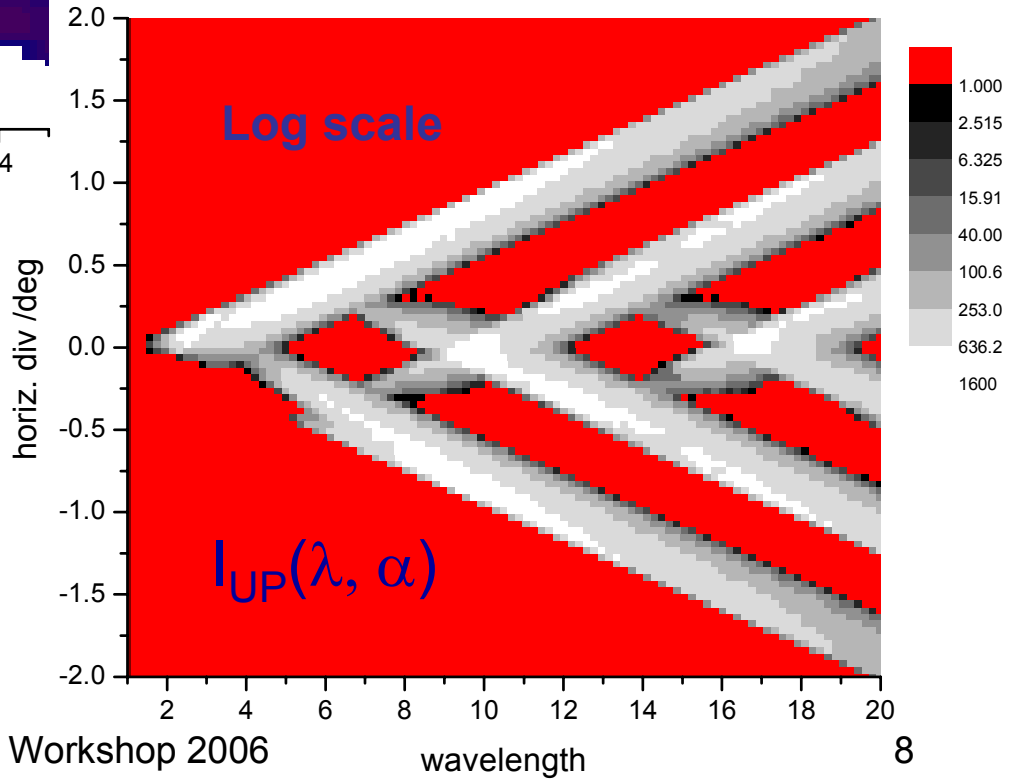
QUESTION: how wavelength and divergence profiles look like ?

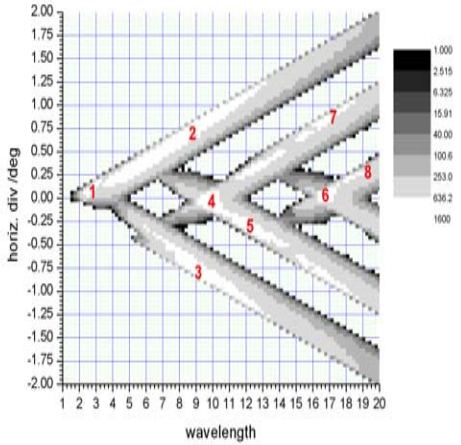


Sm cavity transmission

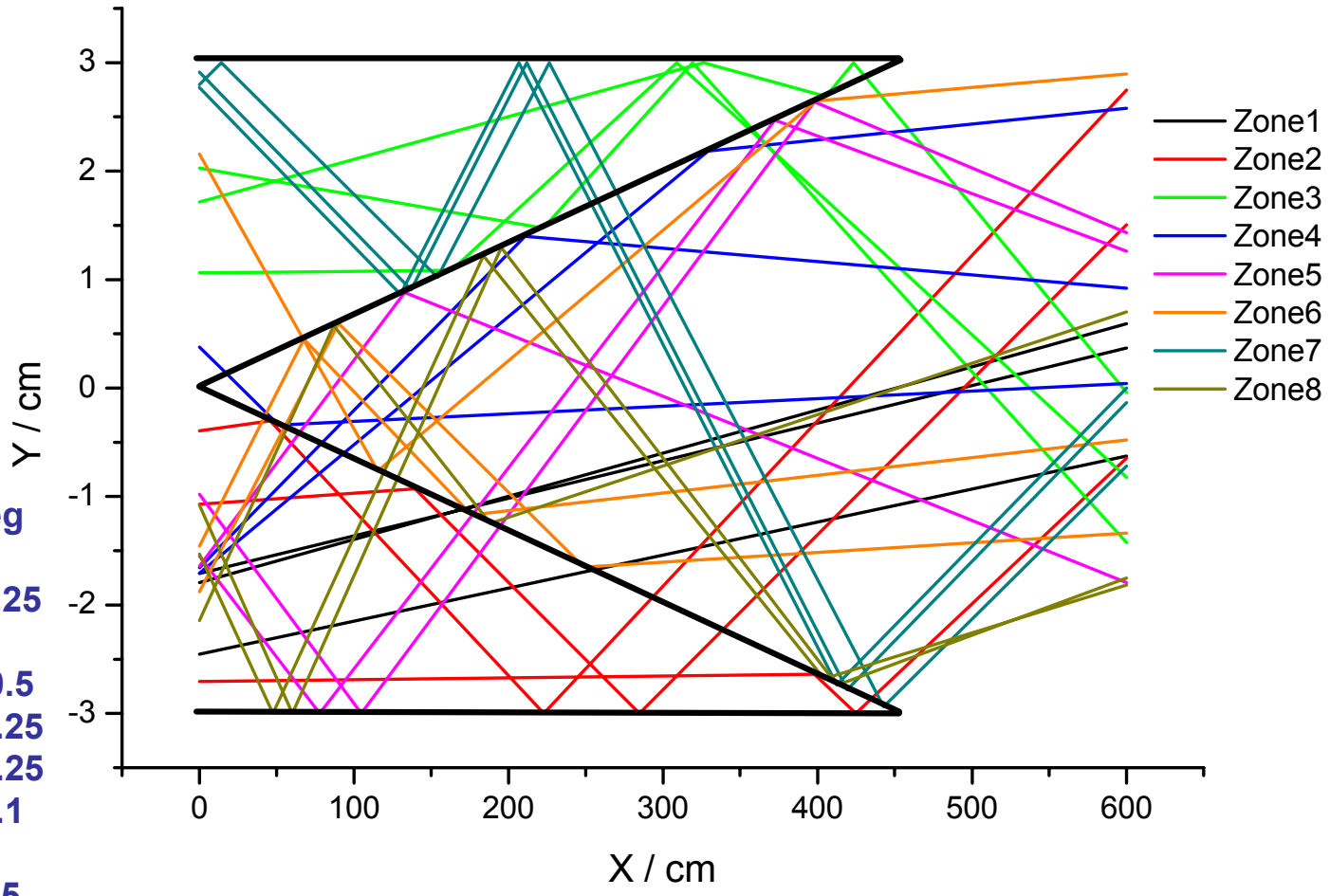
Small contamination of

Up - transmitted





Three example trajectories from each zone.



Zone	Δλ / Å	Δθ /deg
1	2 - 3.25	0.0 - 0.25
2	8 – 10	0.5 - 1
3	8 – 10	-1.0 - -0.5
4	9.5 - 10.5	-0.25 - 0.25
5	11.5 - 13.5	-0.35 - 0.25
6	16.5 - 17.5	-0.1 - 0.1
7	16 – 19	0.75 - 1
8	18 – 20	0.25 - 0.5

New ultra cold neutron (UCN) optics components

New UCN optics components

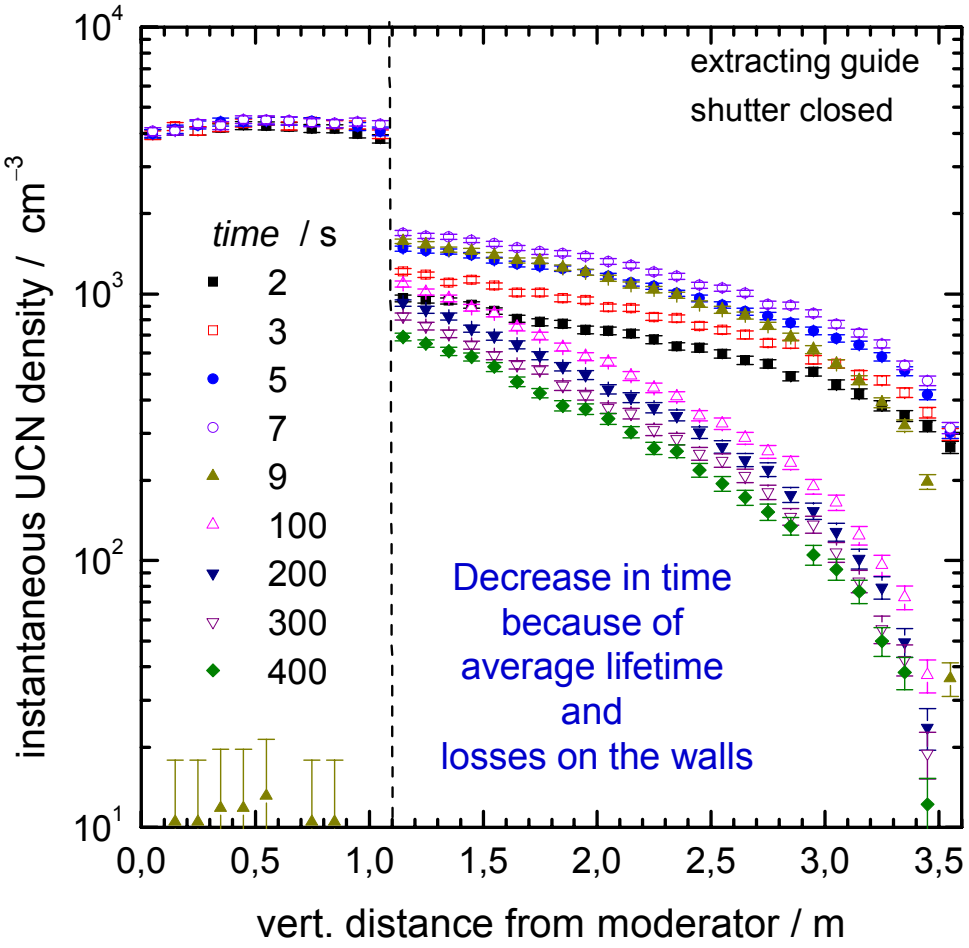
*NEW UCN SIMULATION CODE: **MCUCN***

- Tracking in complex geometry
- Gravity considered.
- Specular and diffuse reflections.
- Average lifetime τ_{decay} = 886 s.
- Loss, reflectivity:

$$\mu = 1 - R = 2\eta\sqrt{E_0/(U - E_0)}$$

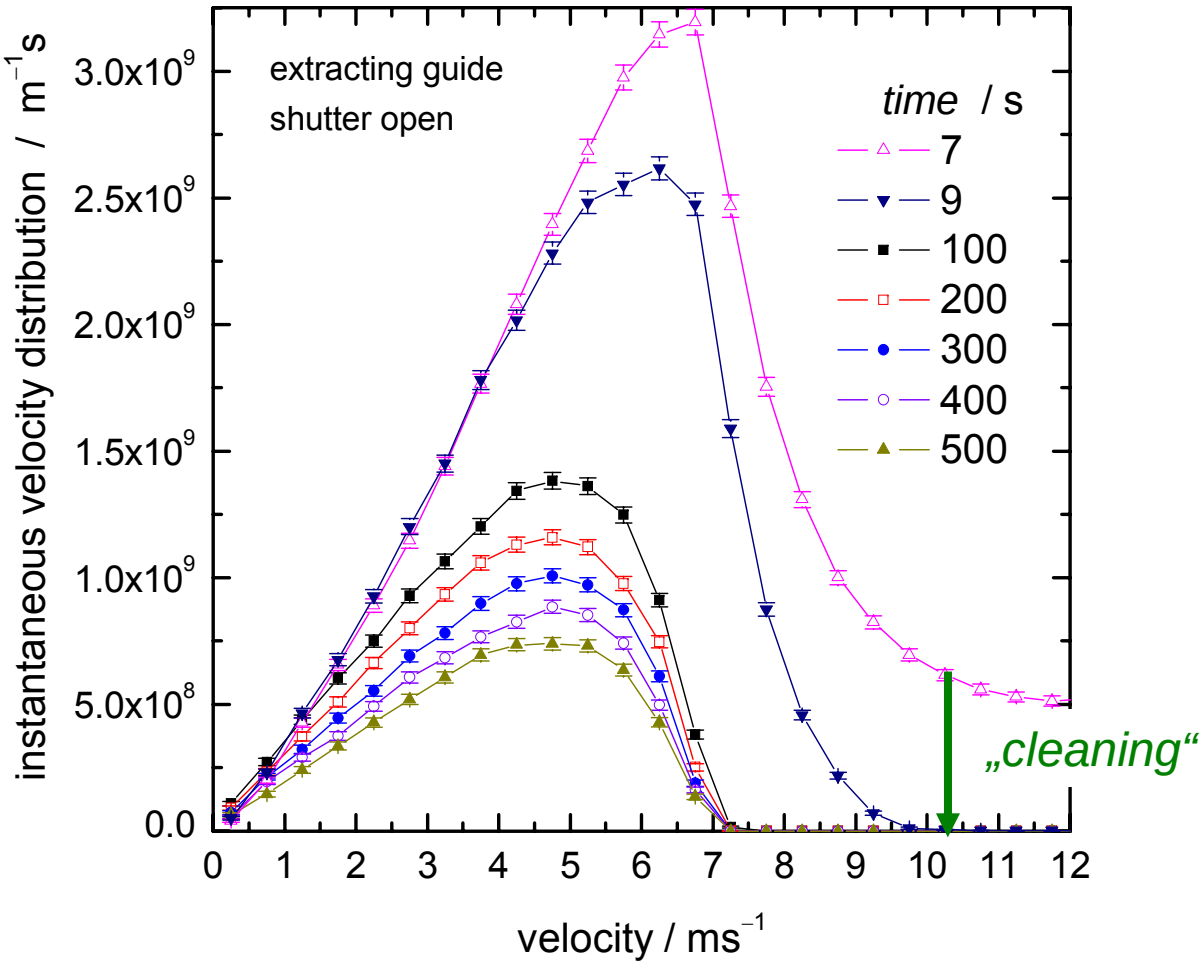
$$U = \frac{2\pi\hbar^2}{m}\rho\,\mathrm{Re}\,b$$

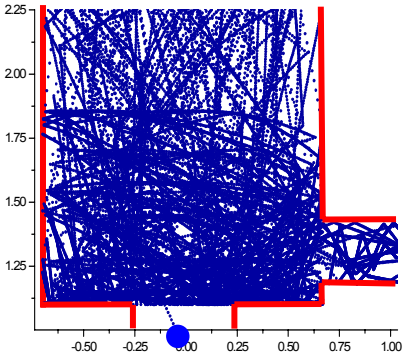
$$\eta = \mathrm{Im}\,b/\mathrm{Re}\,b$$



Spin flipping will be included soon

New UCN optics components



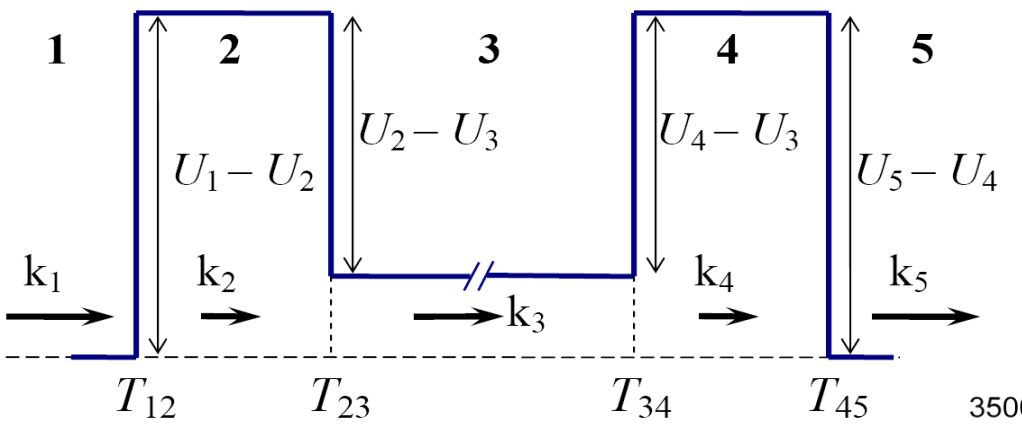


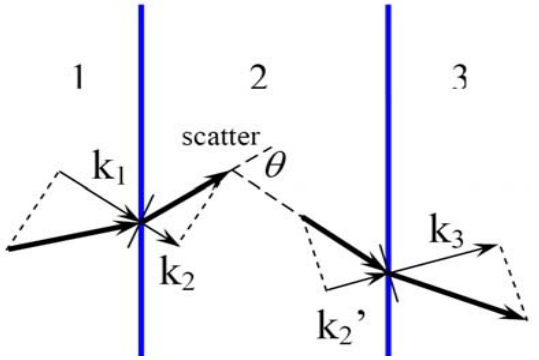
- Calculated UCN velocity distributions $f_t(v)$ at different moments of time.
- The boundary velocity is determined by the diamond-like carbon (DLC) coating: $v_{\perp\ \mathrm{critical}} = 6.89$ m/s

Virtual experiment example:
MC data evaluation of the Fermi potential

Use of virtual experiments

Measurement of the Fermi potential – MC data analysis





E.g.: Be-Si-Be Fermi-potential profile

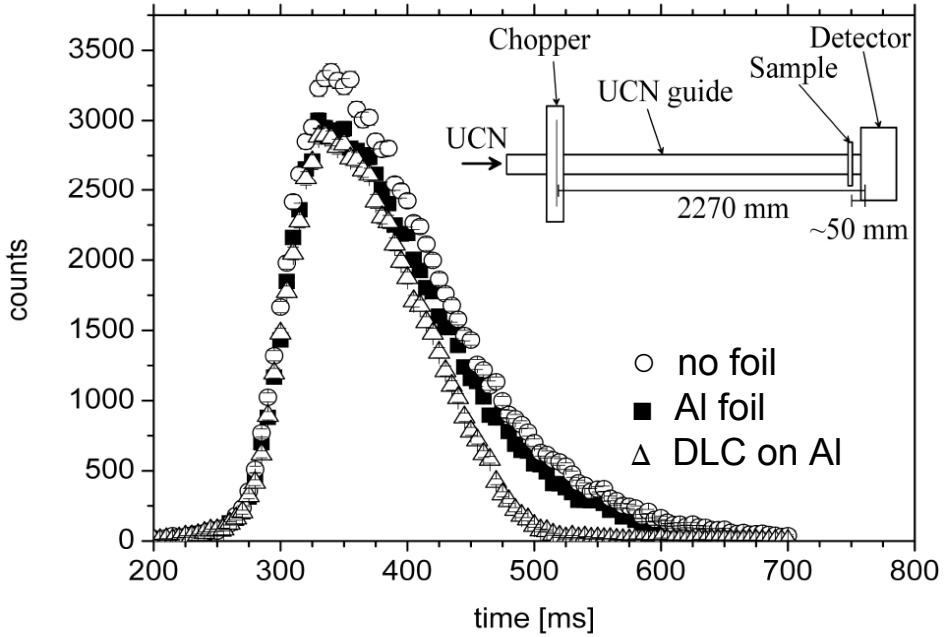
$$k_{i+1} = \left[k_i^2 + 2m\left(U_i - U_{i+1}\right)/\hbar^2\right]^{1/2}$$

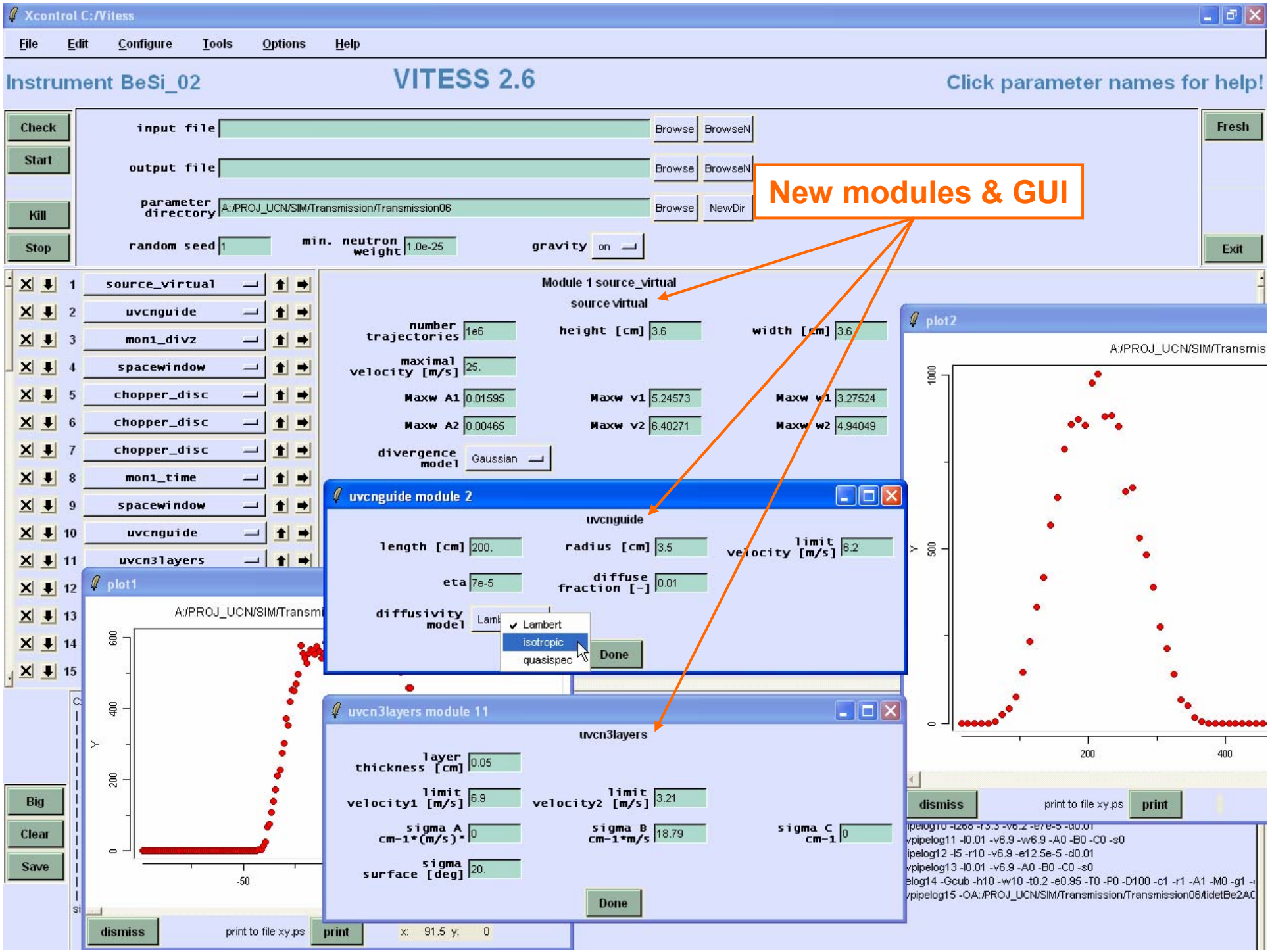
$$T_{i(i+1)} = \frac{4k_i k_{i+1}}{\left|k_i + k_{i+1}\right|^2}$$

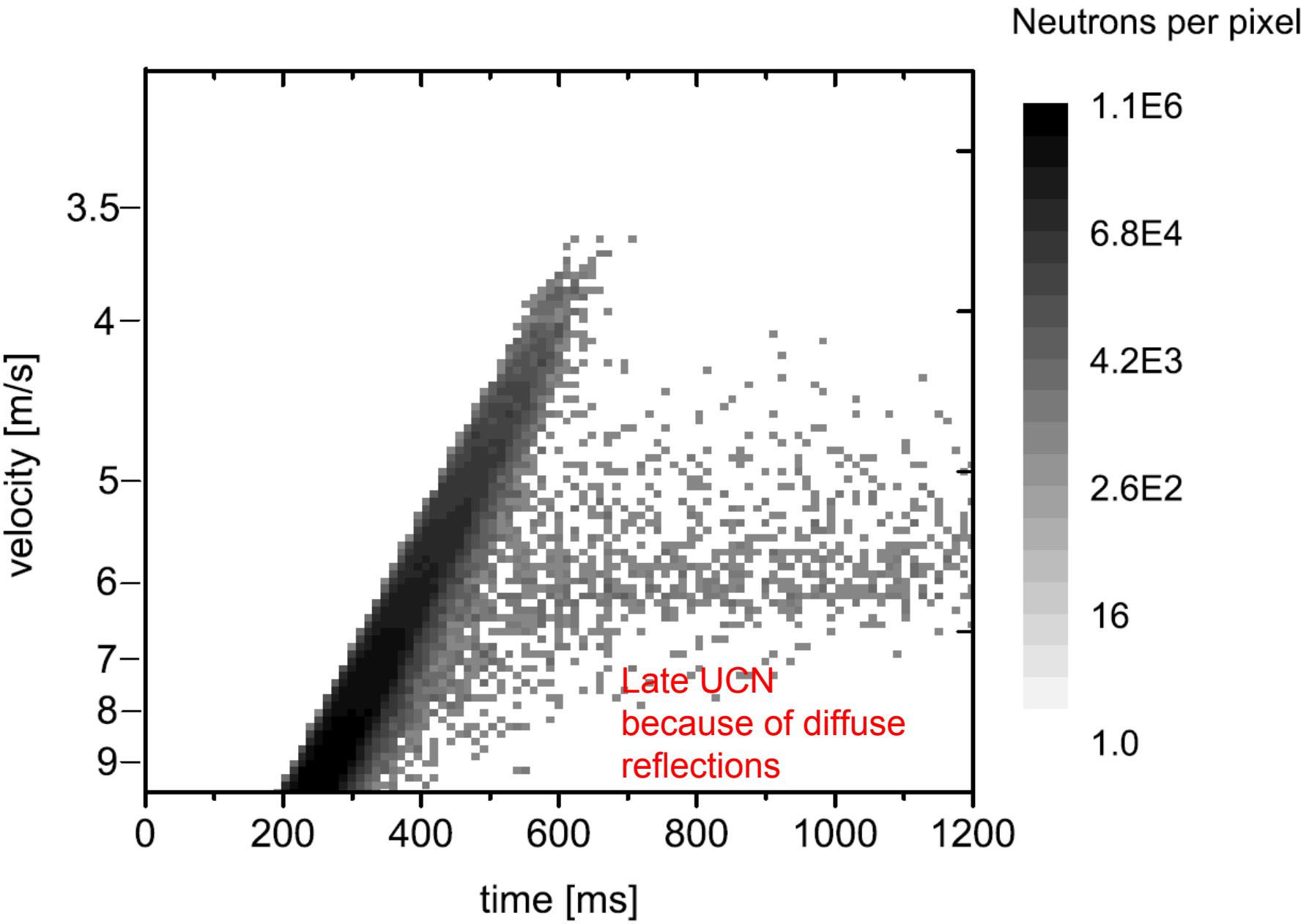
$$\alpha_i = \exp(-\Sigma_t^i l_i)$$

$$l_i = d_i/\cos\theta_i$$

$$\tau = \prod_i \alpha_i T_{i(i+1)}$$

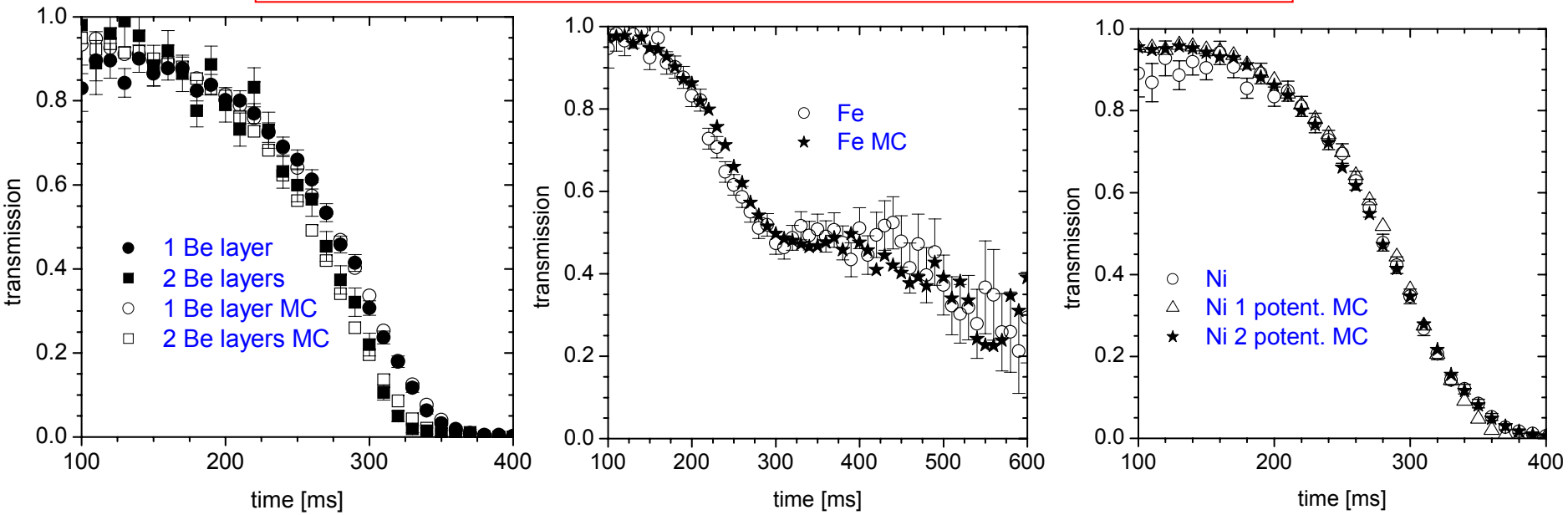



Xcontrol C:/Vitess
File Edit Configure Tools Options Help
Instrument BeSi_02
VITESS 2.6
Click parameter names for help!
Check
Start
Kill
Stop
Fresh
Exit
input file
output file
parameter directory
A:/PROJ_UCN/SIM/Transmission/Transmission06
Browse
BrowseN
NewDir
random seed
min. neutron weight
gravity
on
New modules & GUI
source_virtual
uvcnguide
mon1_divz
spacewindow
chopper_disc
mon1_time
uvcn3layers
Module 1 source_virtual
source virtual
number trajectories
height [cm]
width [cm]
maximal velocity [m/s]
Maxw A1
Maxw A2
Maxw v1
Maxw v2
Maxw w1
Maxw w2
divergence model
Gaussian
uvcnguide module 2
uvcnguide
length [cm]
radius [cm]
limit velocity [m/s]
eta
diffuse fraction [-]
diffusivity model
Lambert
isotropic
quasispec
Done
plot1
plot2
A:/PROJ_UCN/SIM/Transmis
dismiss
print to file xy.ps
print
uvcn3layers module 11
uvcn3layers
layer thickness [cm]
limit velocity1 [m/s]
limit velocity2 [m/s]
sigma A cm-1*(m/s)*
sigma B cm-1*m/s
sigma C cm-1
sigma surface [deg]
Big
Clear
Save


Neutrons per pixel
1.1E6
6.8E4
4.2E3
2.6E2
16
1.0
velocity [m/s]
3.5
4
5
6
7
8
9
0
200
400
600
800
1000
1200
time [ms]
Late UCN
because of diffuse
reflections

Use of virtual experiments

Measurement of the Fermi potential – **MC data analysis**



Sample	v_c [m/s] table data	v_c [m/s] TOF - VITESS	V_{Fermi} [neV] TOF - VITESS
Be on Si	6.94	6.9 ± 0.2	249 ± 14
Fe ↑↑	8.09	8.2 ± 0.2	351 ± 14
Fe ↑↓	3.86	3.7 ± 0.2	72 ± 8
Ni ↑↑ on Si	7.36	7.3 ± 0.2	279 ± 15
Ni ↑↓ on Si	6.29	6.4 ± 0.2	214 ± 14

More in Phys. Lett. B (accepted) and Phys. Rev. C (submitted)

Outlook

✓ Polarization VITESS – great efforts made & more to come

✓ New UCN optics components to be adapted for *cold neutrons*

✓ *Virtual experiments* as very effective routine tools *for data analysis*