

Erik Bergbäck Knudsen

Polarization in McStas



Mcstas “particle” model recap.

Neutron ray/package:

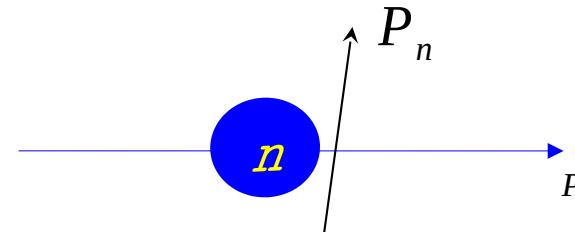
Weight: (p) # neutrons left in the package

Position: (x, y, z)

Velocity: (v_x, v_y, v_z)

Polarization: (s_x, s_y, s_z)

Time: (t)



“sub ray” level

$$P_{i,n} = 2 \left(\langle \hat{s}_{x,i} \rangle \hat{i}_{x,i} + \langle \hat{s}_{y,i} \rangle \hat{i}_{y,i} + \langle \hat{s}_{z,i} \rangle \hat{i}_{z,i} \right)$$

From G. Williams: "Polarized neutrons", Oxford Science Publ., 1988

Ray level

$$P_n = \frac{1}{p_n} \sum_i^p P_{i,n}; n = \text{raynumber}$$

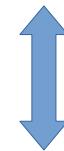
Beam level

$$P = \frac{1}{N} \sum_{n=0}^N P_n$$



Unpolarized beam

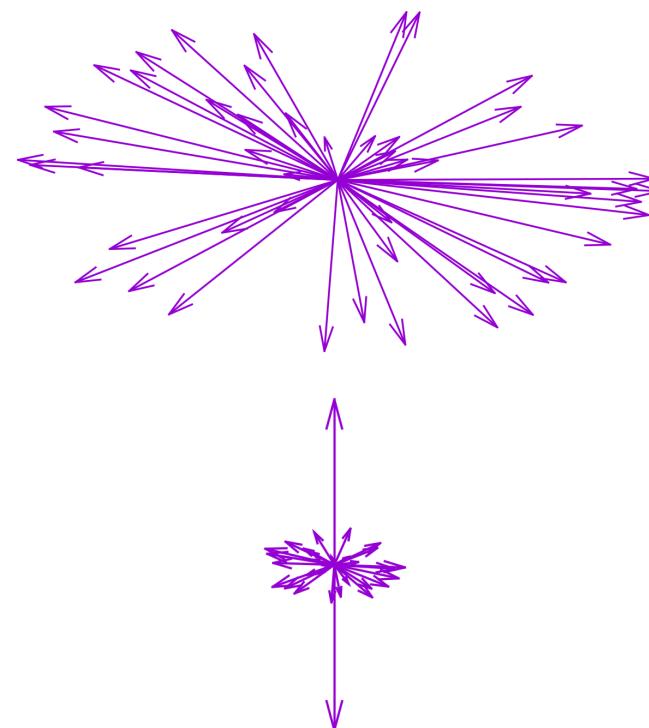
$$\hat{s}_i = (s_x, s_y, s_z) = (0, 0, 0); \quad \forall \hat{s}_i$$



\bar{s} = random unit vector



$$|\sum \bar{s}| = 0$$



Complete polarization
information in each ray

Polarization components in McStas 2.7

Magnetic fields:

- `Pol_FieldBox.comp`
- `Pol_constBfield.comp`
- `Pol_Bfield.comp`
- `Pol_Bfield_stop.comp`
- `Pol_triafield.comp`

Monitors:

- `Pol_monitor.comp`
- `MeanPolLambda_monitor.comp`
- `PolLambda_monitor.comp`

Contrib:

- `Foil_flipper_magnet.comp`
- `Single_magnetic_crystal.comp`

Optics:

- `Monochromator_pol.comp`
- `Pol_bender.comp`
- `Pol_guide_vmirror.comp`
- `Pol_mirror.comp`
- `Pol_pi_2_rotator.comp`
- `Transmission_polarisatorABSnT.comp`
- `Pol_bender_tapering.comp`
- `Pol_straight_tapering.comp`
- `He3_cell.comp`
- `RF_flipper.comp`

Idealized components:

- `PolAnalyser_ideal.comp`
- `Set_pol.comp`



Polarization monitors

Available monitors:

- `Pol_monitor.comp`: 0D
- `PolLambda_monitor.comp`: 2D
- `MeanPolLambda_monitor.comp`: 1D

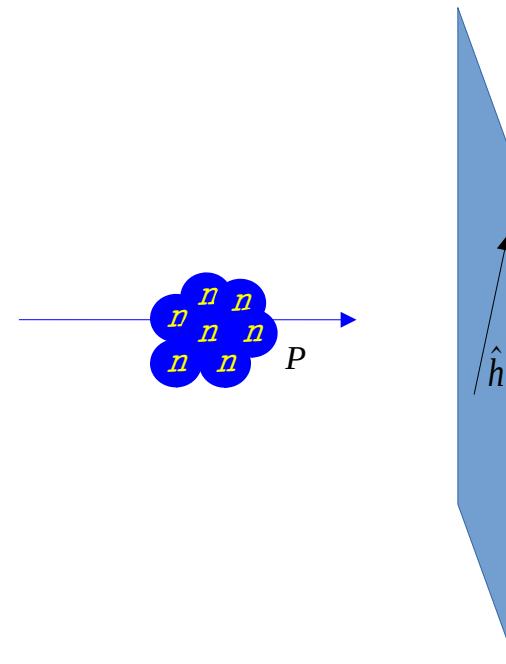
In the repo for next release

- `PolTOF_monitor.comp`: 2D



McStas polarization detectors/monitors

Monitoring: How and What do we monitor?

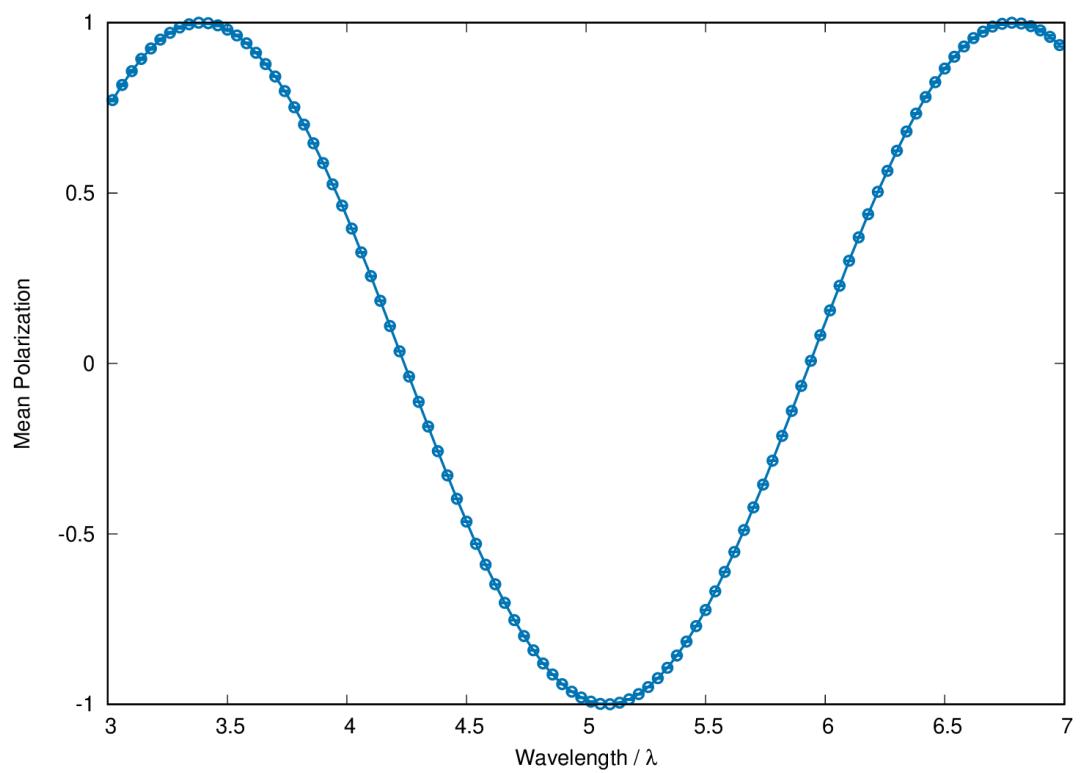
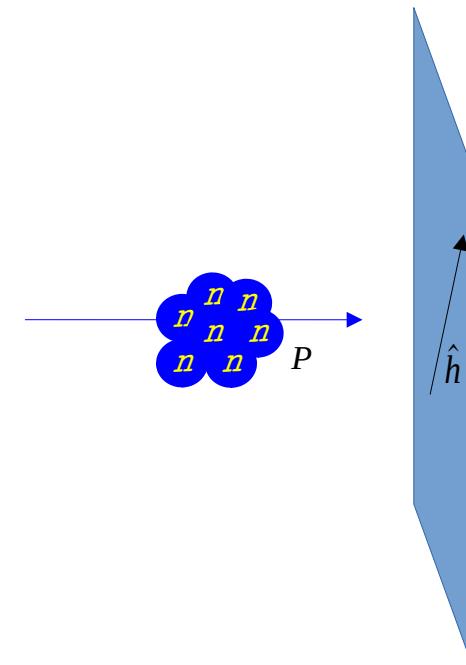


$$P_{\hat{h}} = \frac{\sum_{n=0}^N p_n P_n \cdot \hat{h}}{\sum_n p_n}$$



McStas detectors/monitors

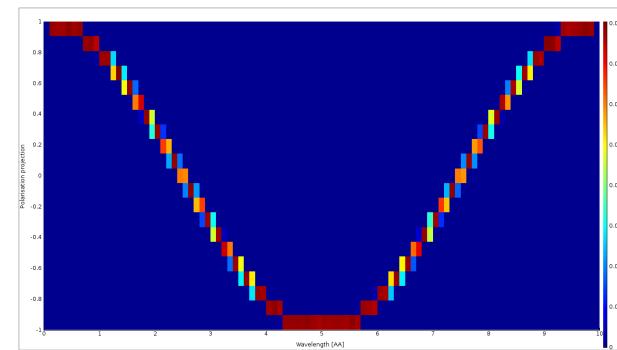
Monitoring: How and What do we monitor?



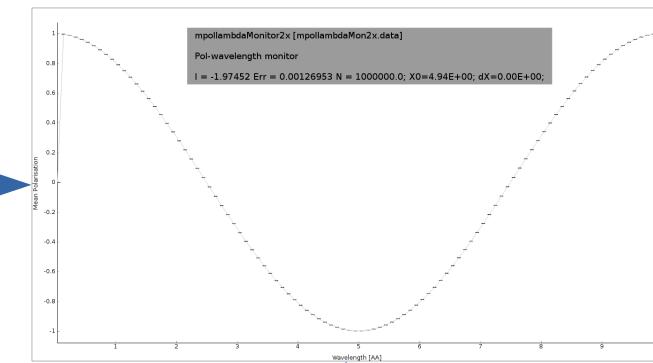


McStas polarization monitors

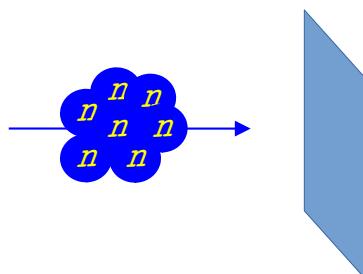
PolLambda_monitor

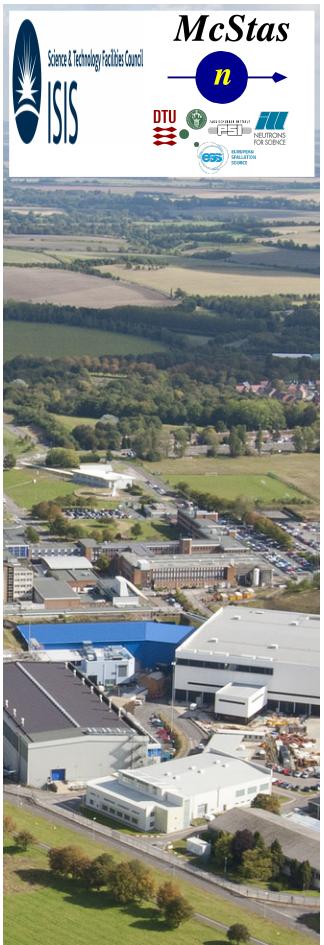


MeanPolLambda_monitor



Pol_monitor
 $P \parallel (m_x, m_y, m_z) = 0.87$

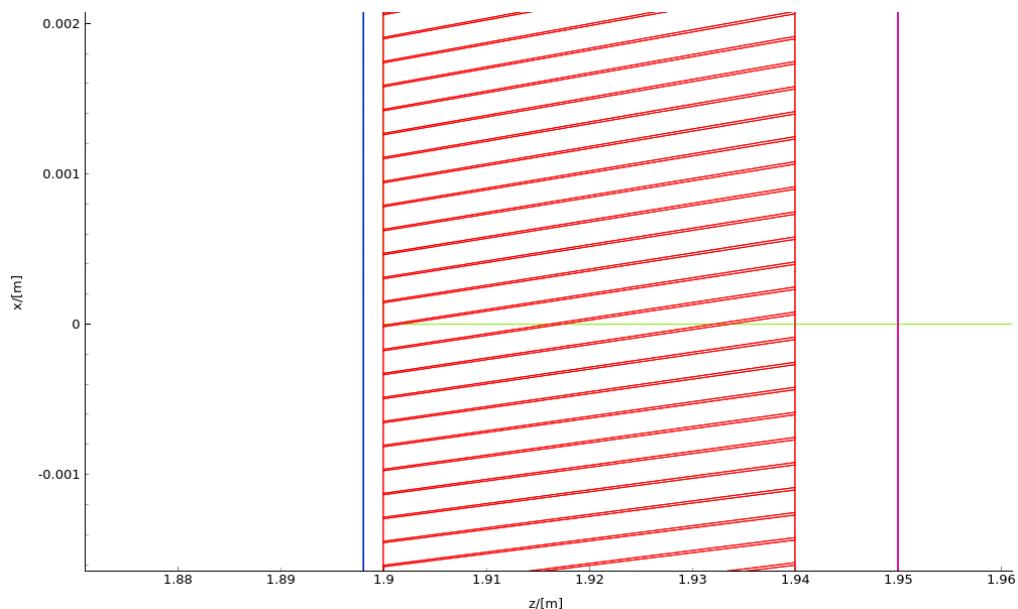




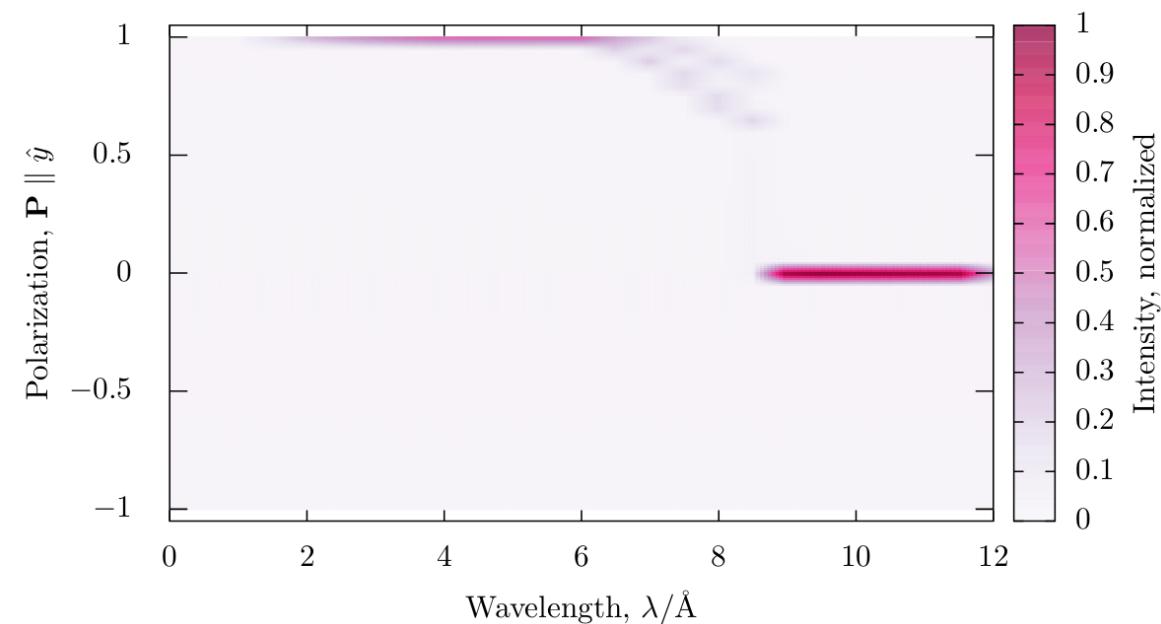
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2D PolLambda_monitor

Solid state polarizer
(Pol_straight_tapering)

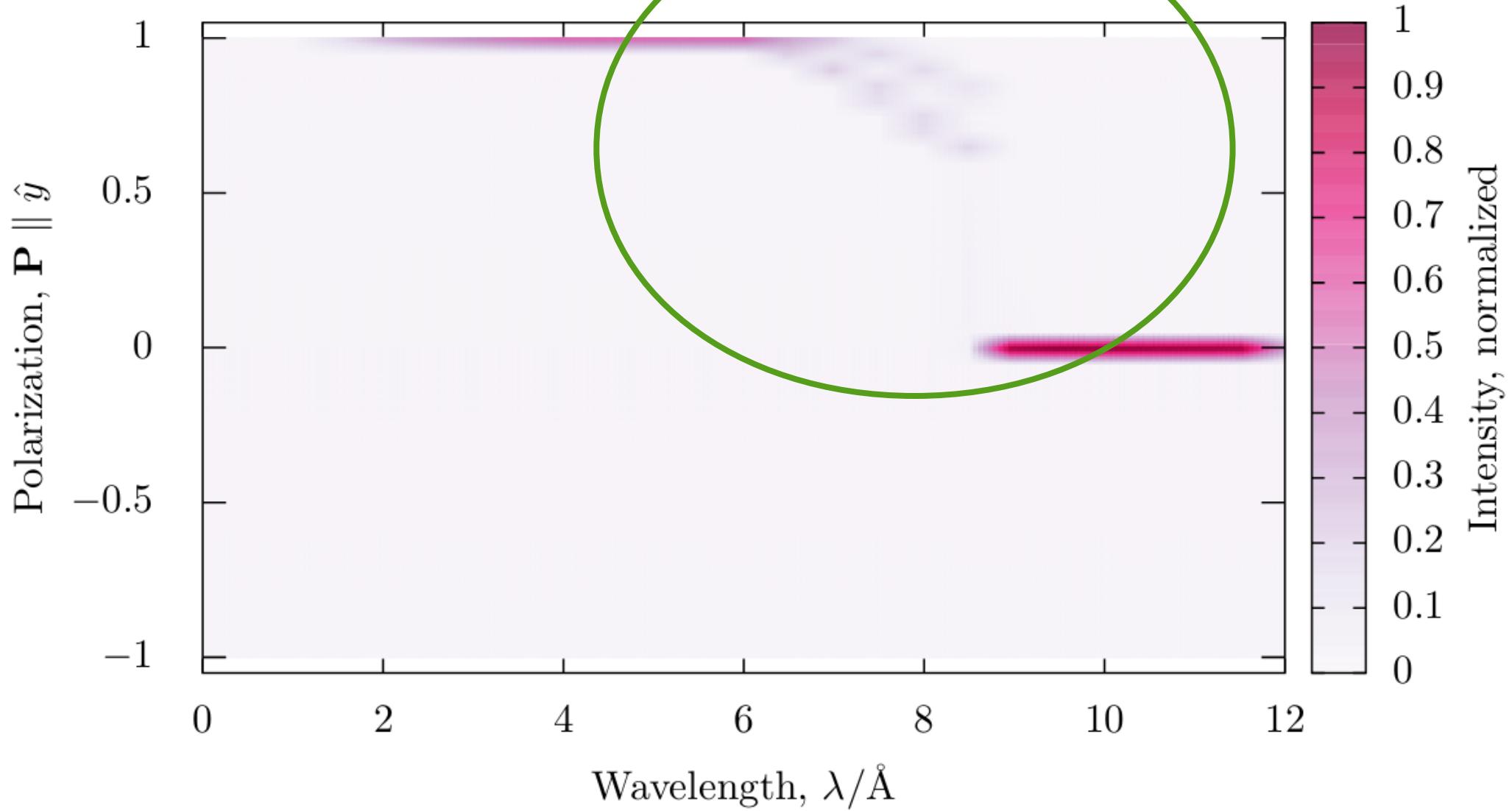


PolLambda_monitor





2D Polarization monitor





McStas precession algorithm

- Magnetic fields in McStas
- The challenge:
 - * Fast beam/ray transport: $rays > 10^6$
 - * Unknown magnetic field and field strength
 - * > 1 Magnet → nested fields.


McStas


McStas precession algorithm

```

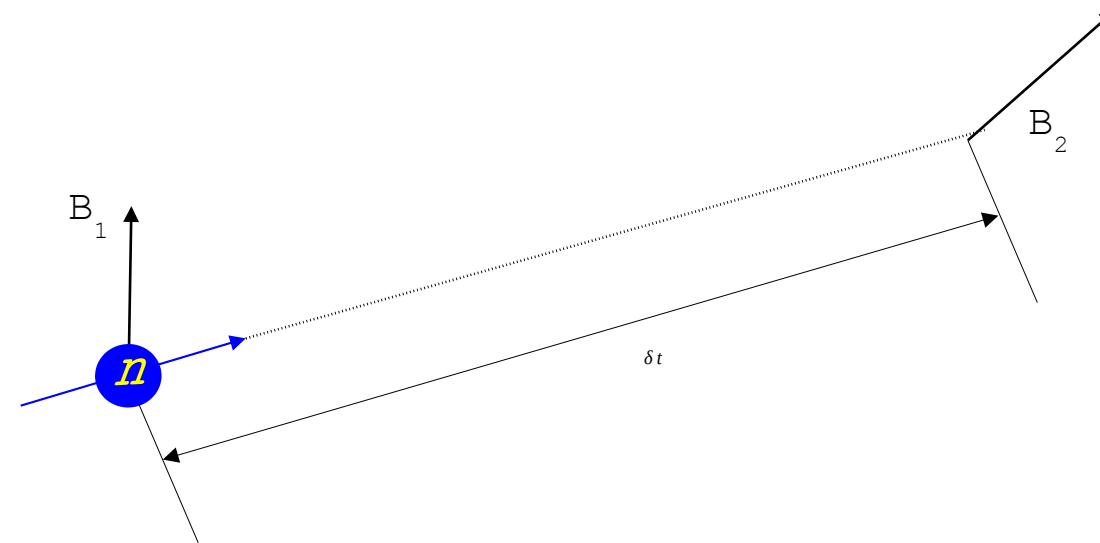
while  $n_t < t_{\text{target}}$  do
  store neutron;
  sample magnetic field:  $\mathbf{B}_1 = \mathbf{B}(n_x, n_y, n_z, n_t)$ ;
  propagate neutron:  $\delta t (< \Delta t)$ ;
  sample magnetic field:  $\mathbf{B}_2 = \mathbf{B}(n_x, n_y, n_z, n_t)$ ;
  while  $|\mathbf{B}_1 - \mathbf{B}_2| > \delta B_{\text{threshold}}$  do
    restore neutron;
     $\delta t := \delta t / 2$ ;
    propagate neutron:  $\delta t (< \Delta t)$ ;
    sample magnetic field:  $\mathbf{B}_1 = \mathbf{B}(n_x, n_y, n_z, n_t)$ ;
    precess polarization:  $\mathbf{P}_n$  by  $\omega$  around  $\frac{\mathbf{B}_1 + \mathbf{B}_2}{2}$ ;
  
```

Algorithm 1: SimpleNumMagnetPrecession: Simplistic algorithm for tracking polarization of a Monte-Carlo neutron in a magnetic field. The neutron's state is stored as a position (n_x, n_y, n_z) , a velocity \mathbf{v} , time n_t , and polarization vector \mathbf{P}_n .

From: Knudsen et.al., *J. Neutron Research*, 2014

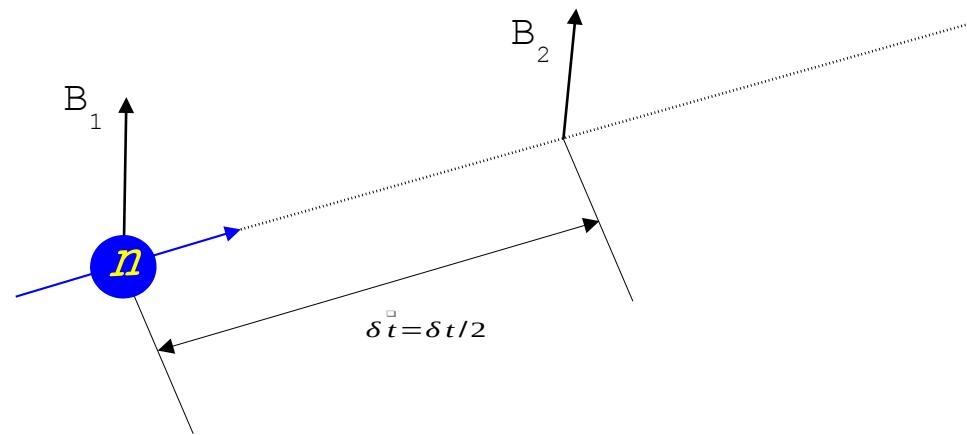


McStas precession algorithm





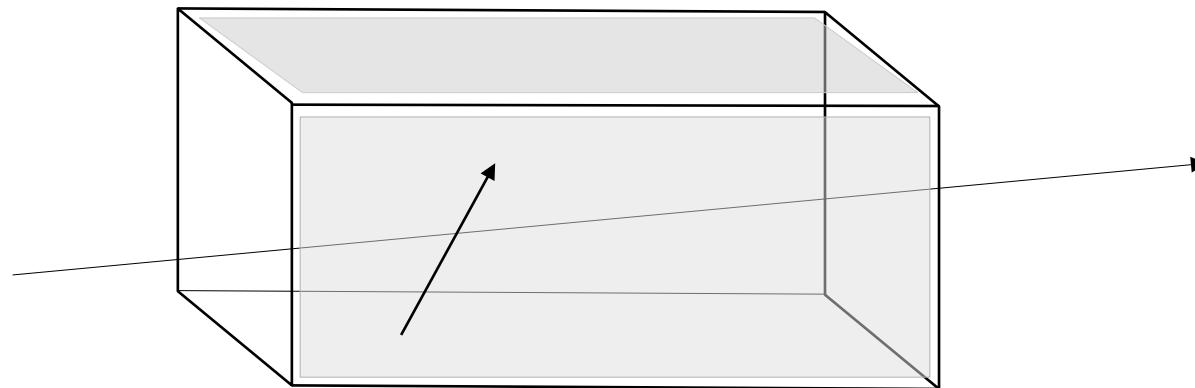
McStas precession algorithm





McStas magnetic fields

- `Pol_constBfield.comp`
- Single constant Magnetic field in a "box".
- - user may specify a wavelength to flip.
- blocking walls

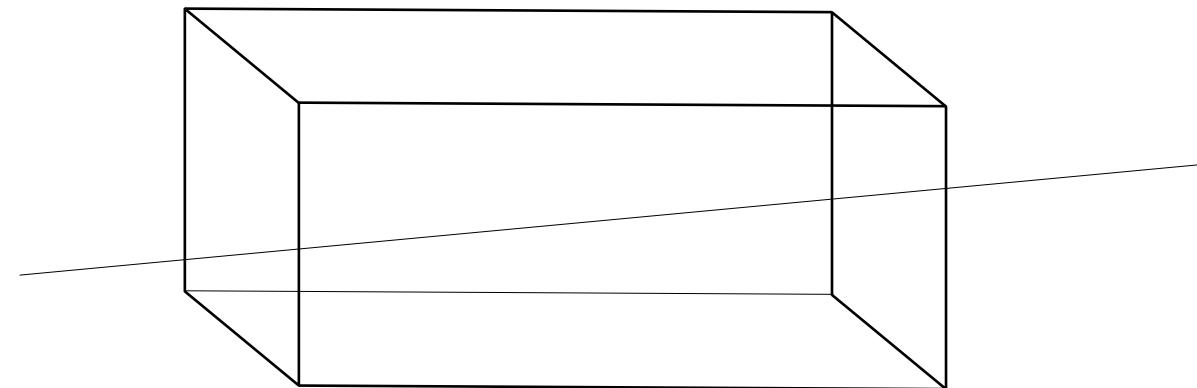




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McStas magnetic fields

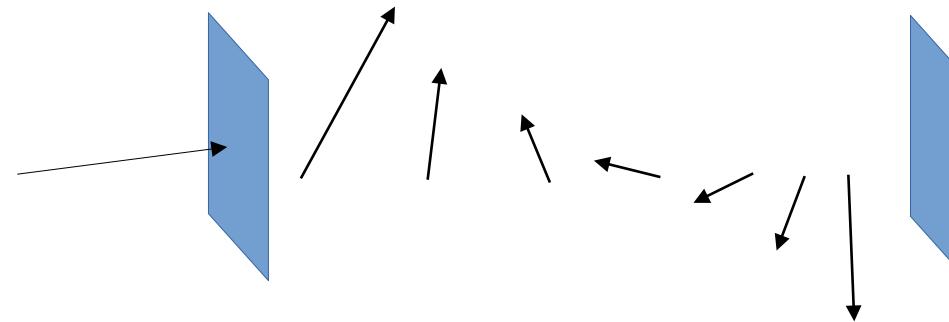
- `Pol_FieldBox.comp`
- Single Magnetic field in a “box”
- - optional user supplied field c-function





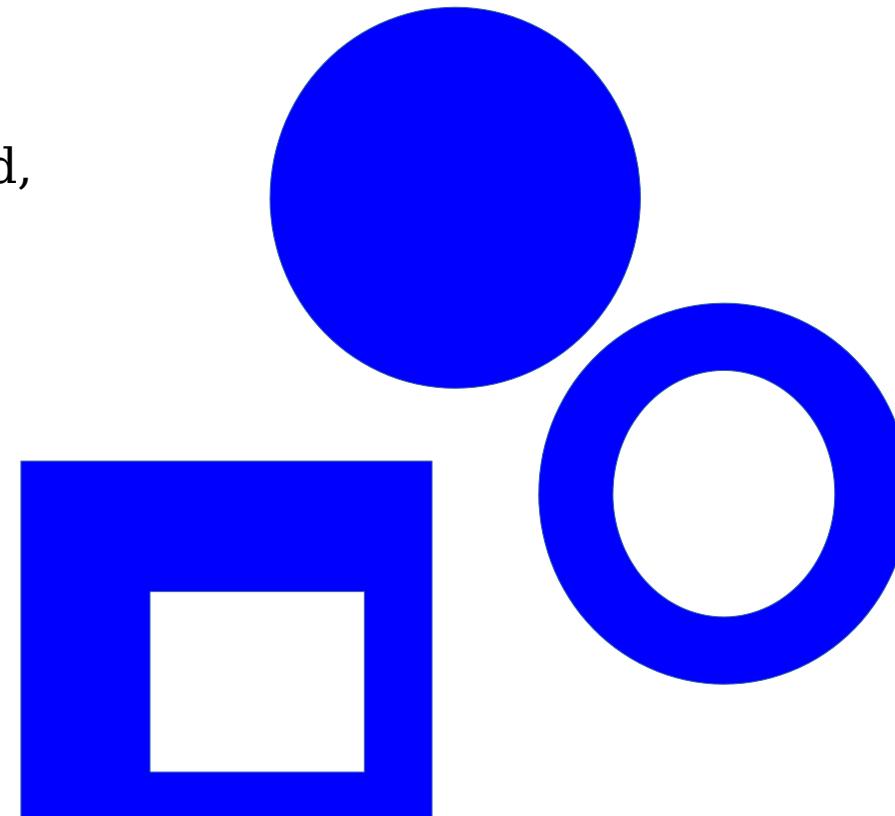
McStas magnetic fields

- Pol_Bfield.comp
- Pol_Bfield_stop.comp
 - - Entry/Exit construction allows for nested magnetic field descriptions.
 - Any magnetic fields through user supplied c-function
 - Tabled magnetic fields





Windows can be many shapes

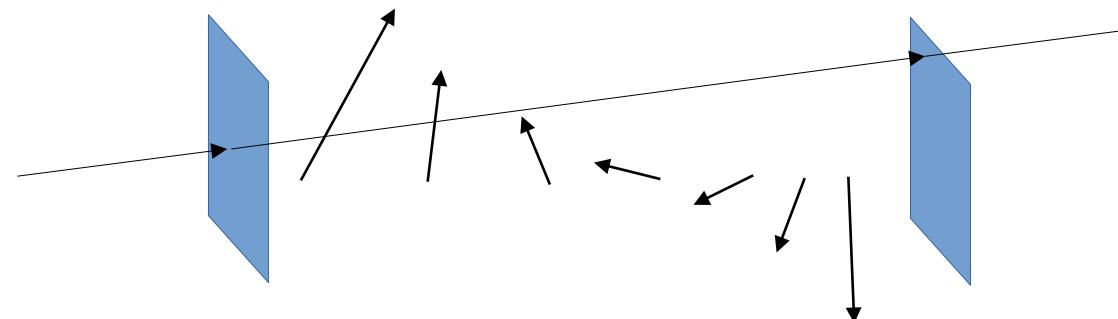


B-Fields: constant, functional, tabled,
... in more general shapes



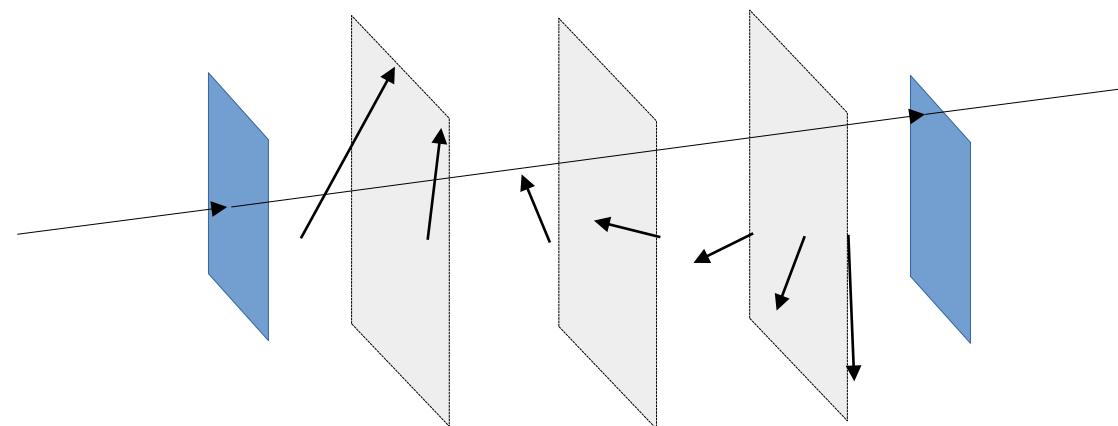
McStas Polarization Capabilities IV

- Pol_Bfield.comp
- Pol_Bfield_stop.comp
 - - Entry/Exit construction allows for nested magnetic field descriptions.
 - Any magnetic fields through user supplied c-function
 - Tabled magnetic fields



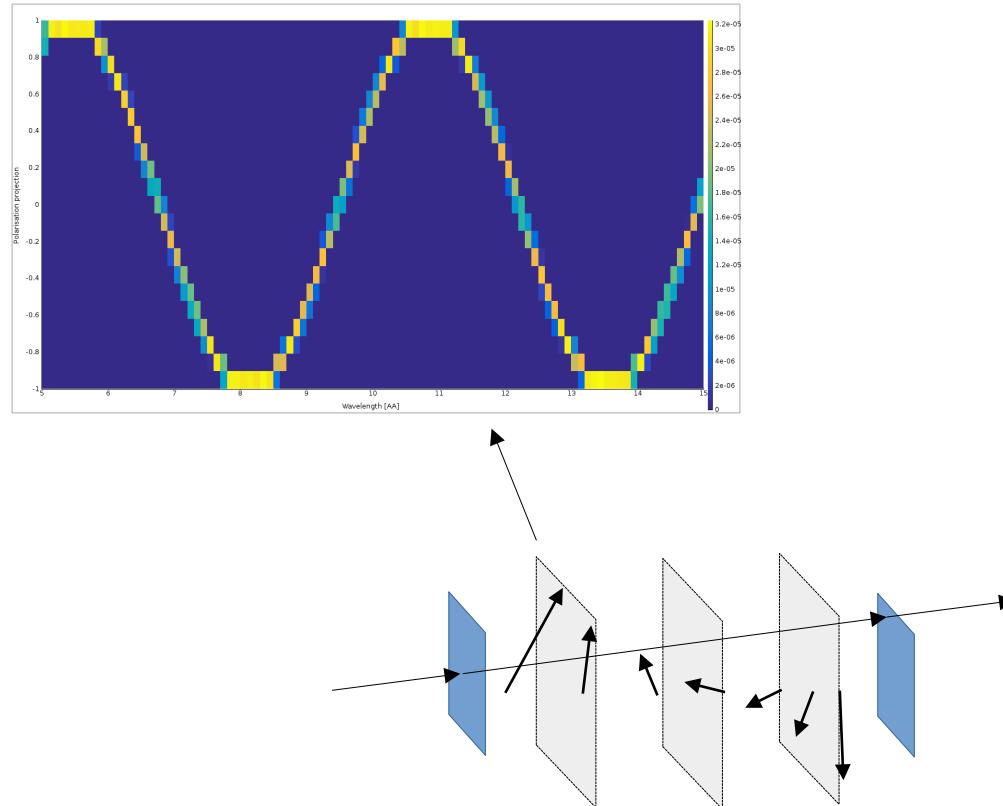


Pol_monitors along the way...



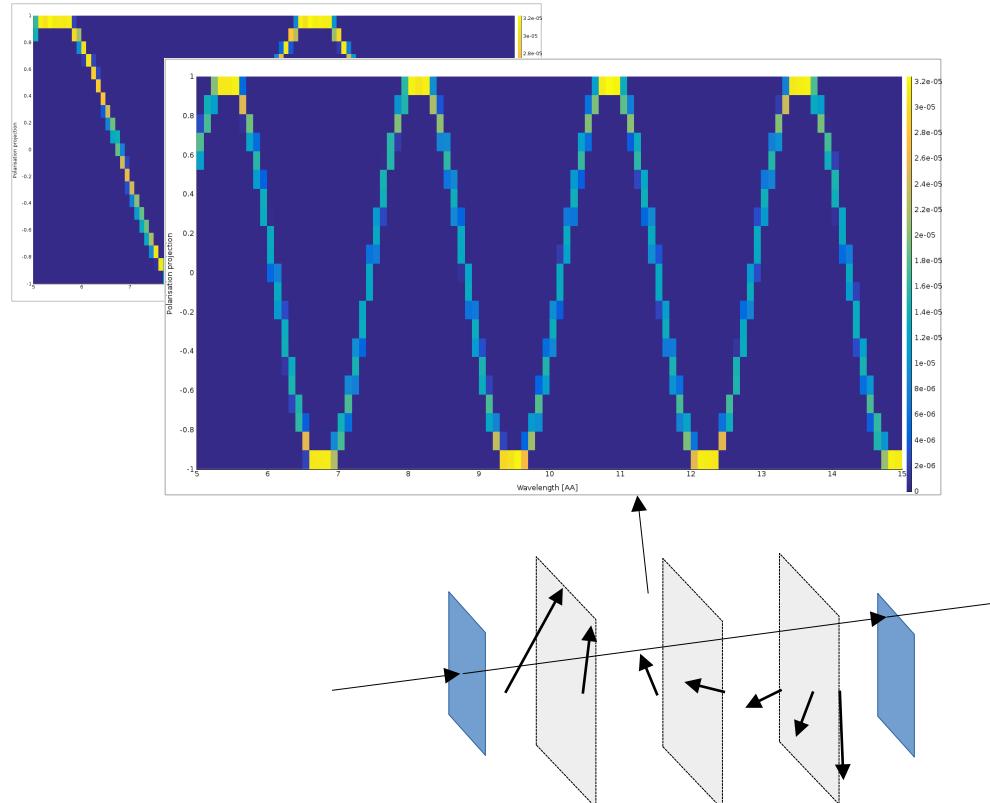


Pol_monitors along the way...



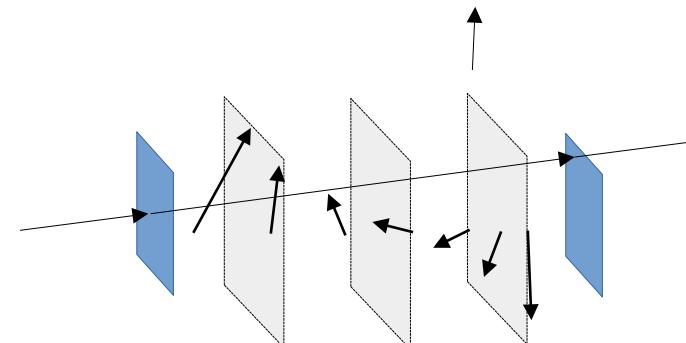
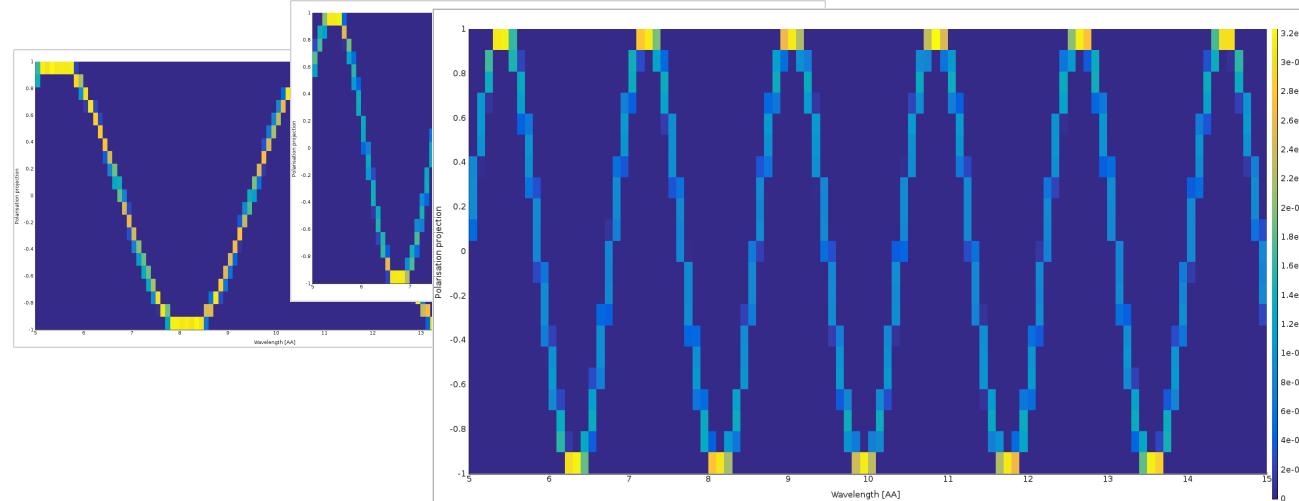


Pol_monitors along the way...



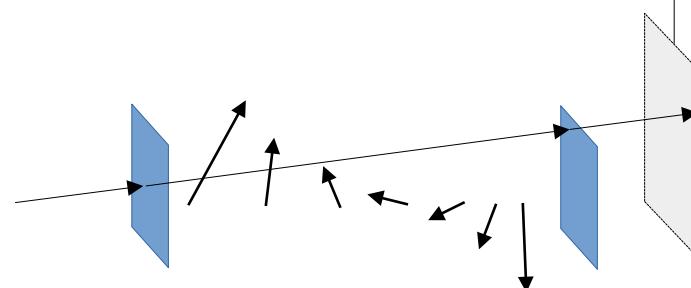
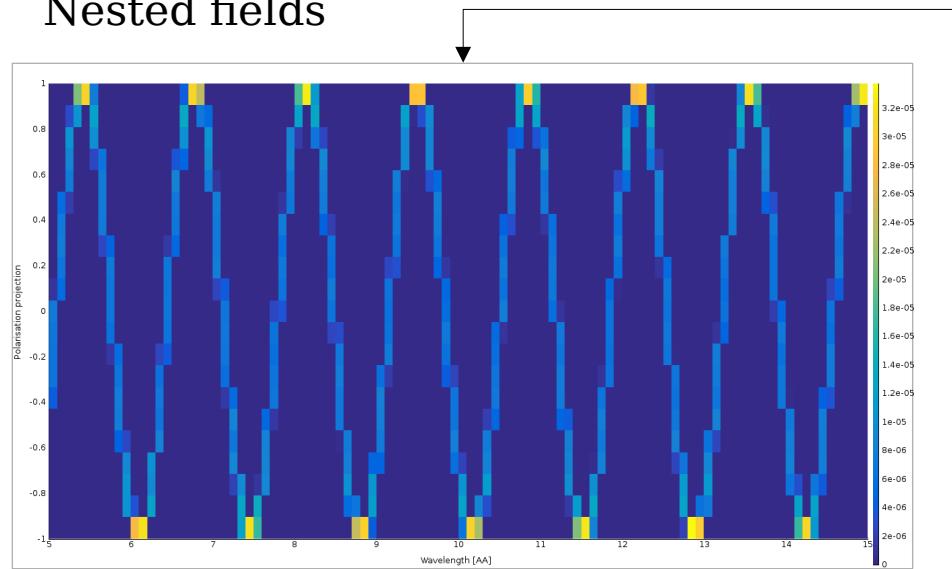


Pol_monitors along the way...



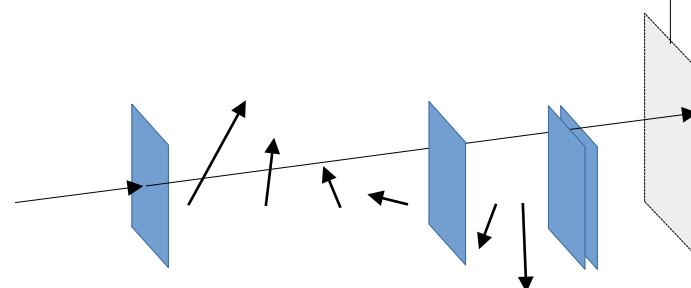
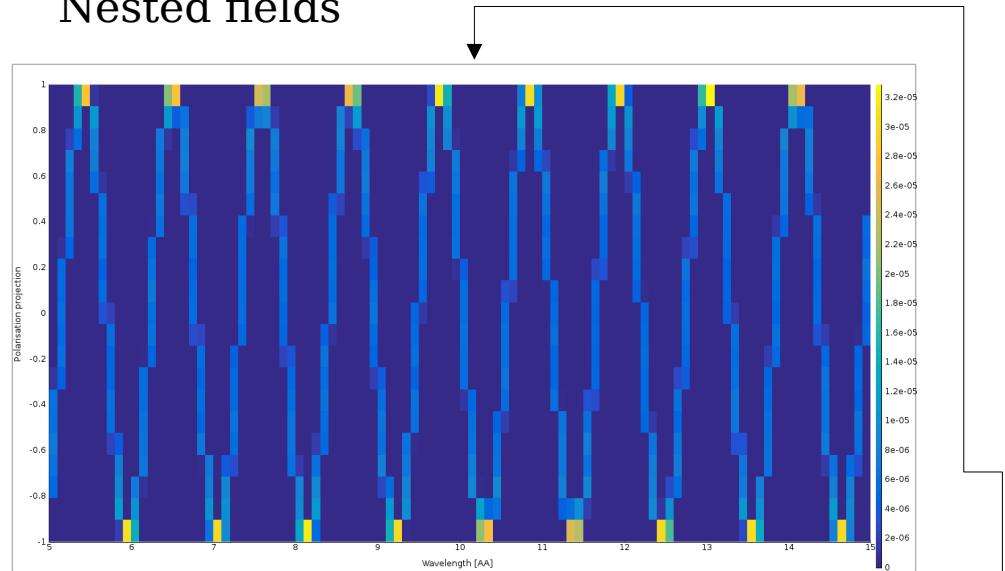


Nested fields





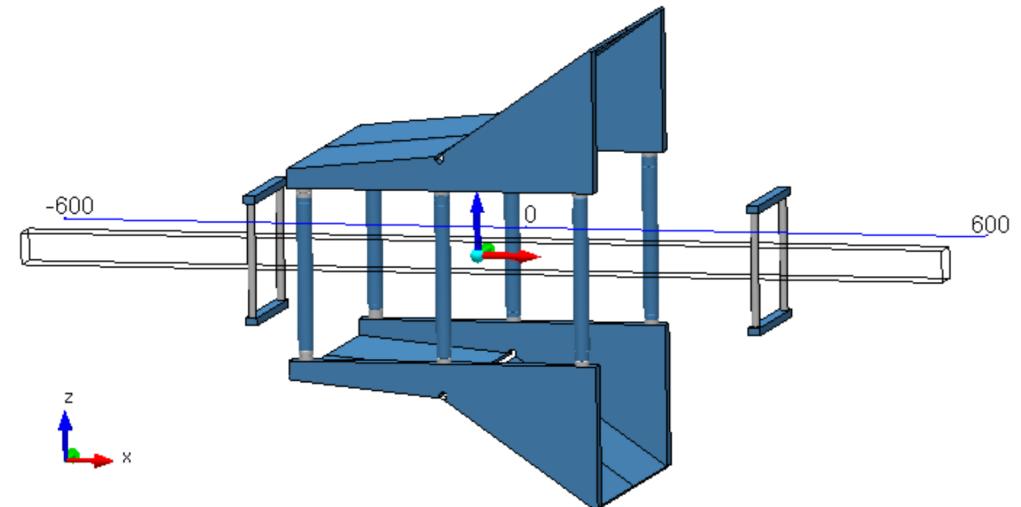
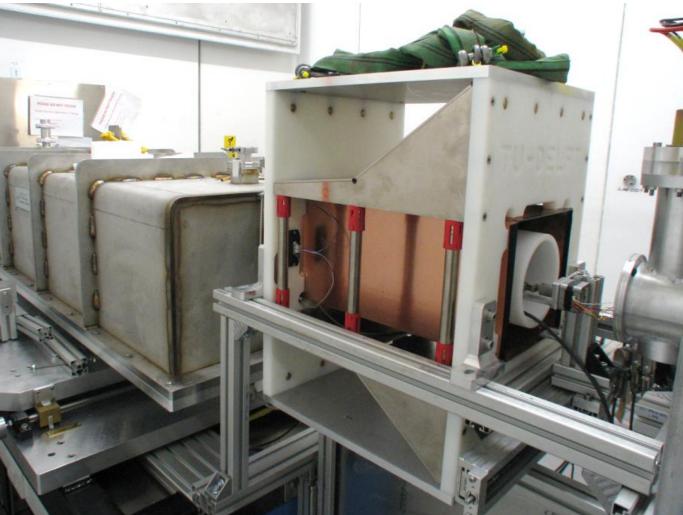
Nested fields





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Use of Bfield to build an RF-flipper

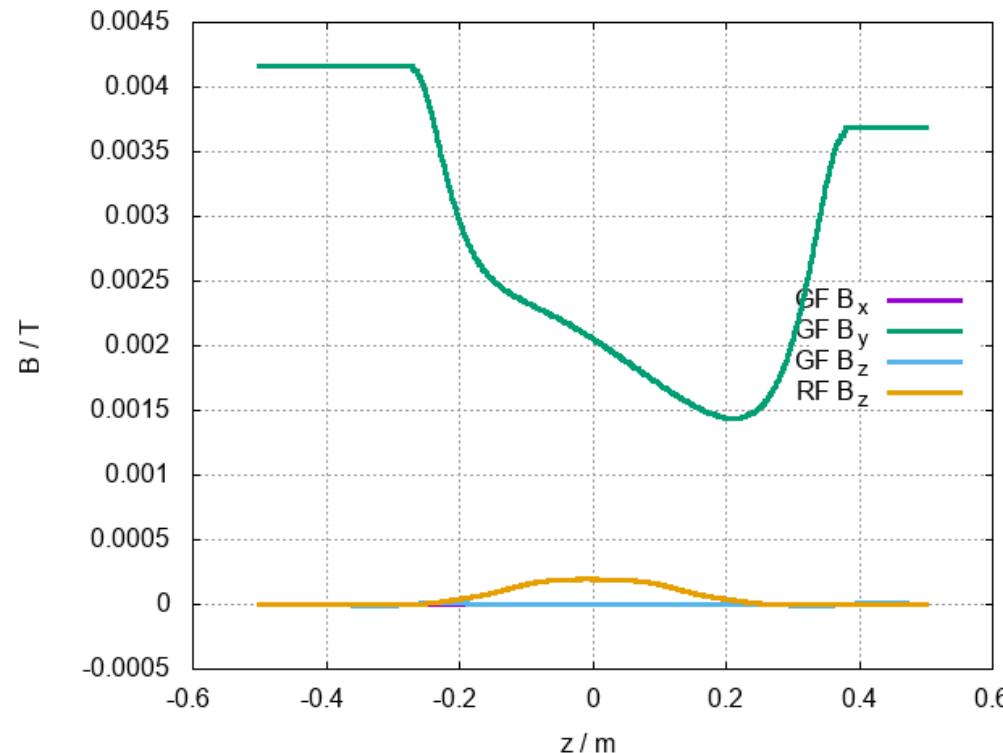


Pictures courtesy of J. Plomp & M. Thijs



Use of Bfield to build an RF-flipper

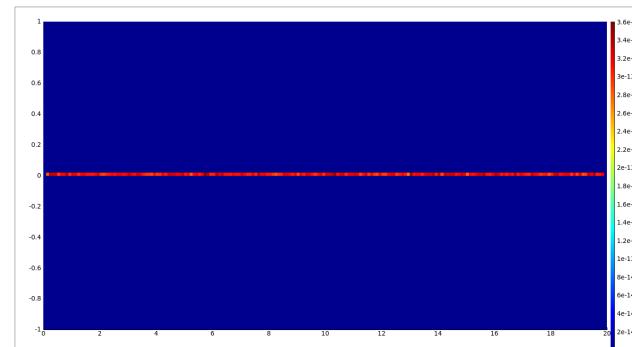
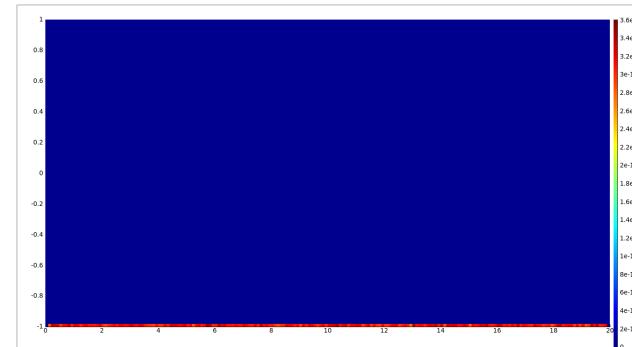
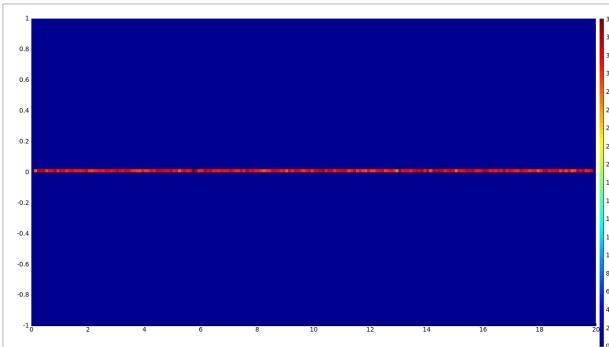
Tabled fields where the RF field is a rotating frame.



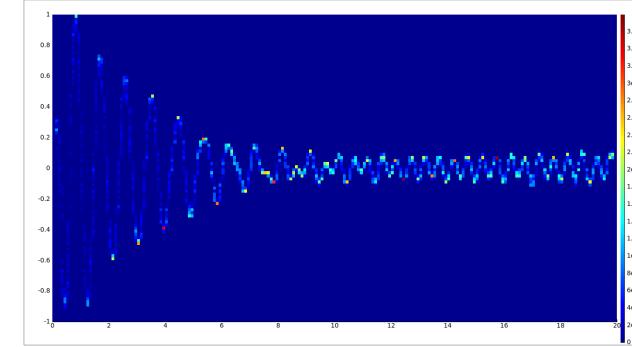
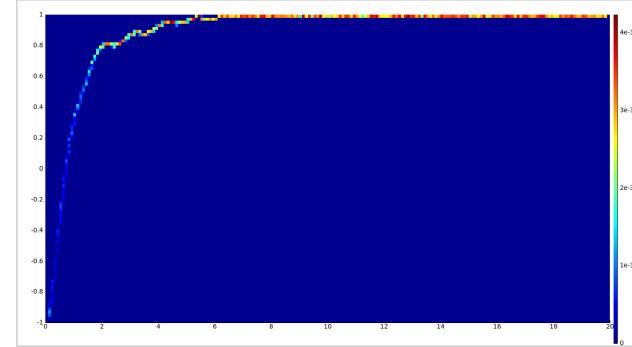
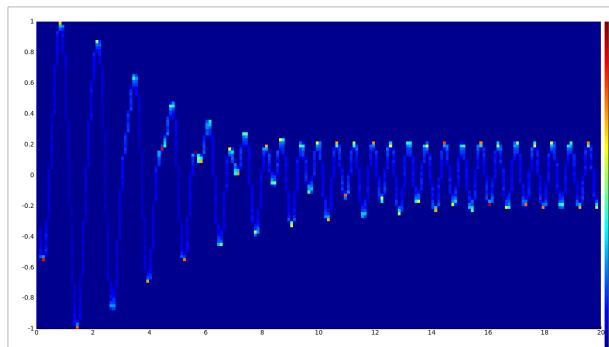


Use of Bfield to build an RF-flipper

Before flipper



After flipper

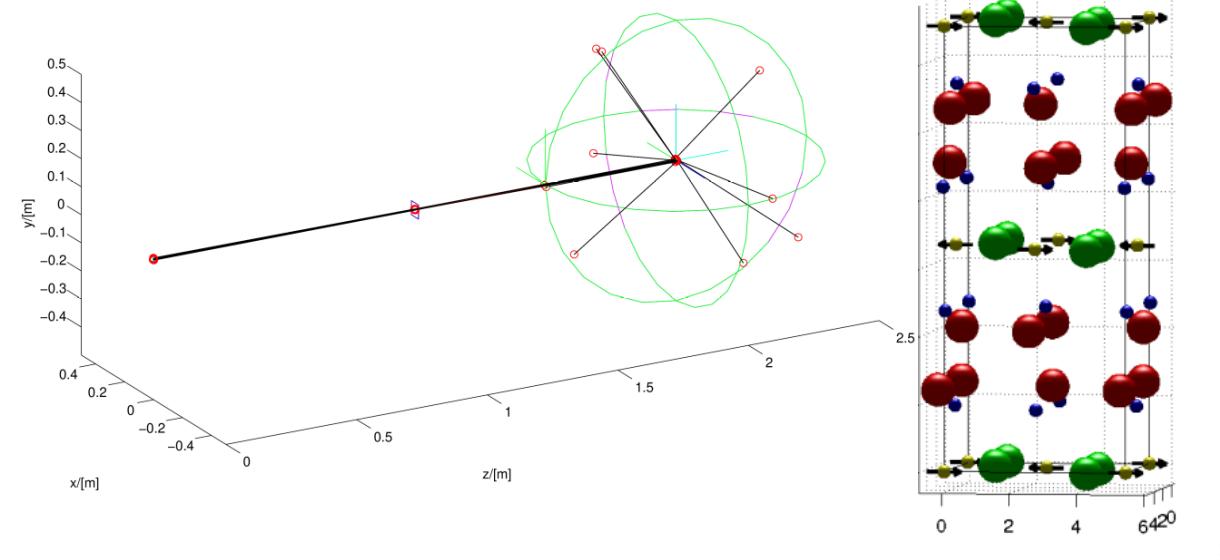


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Magnetic Single crystal



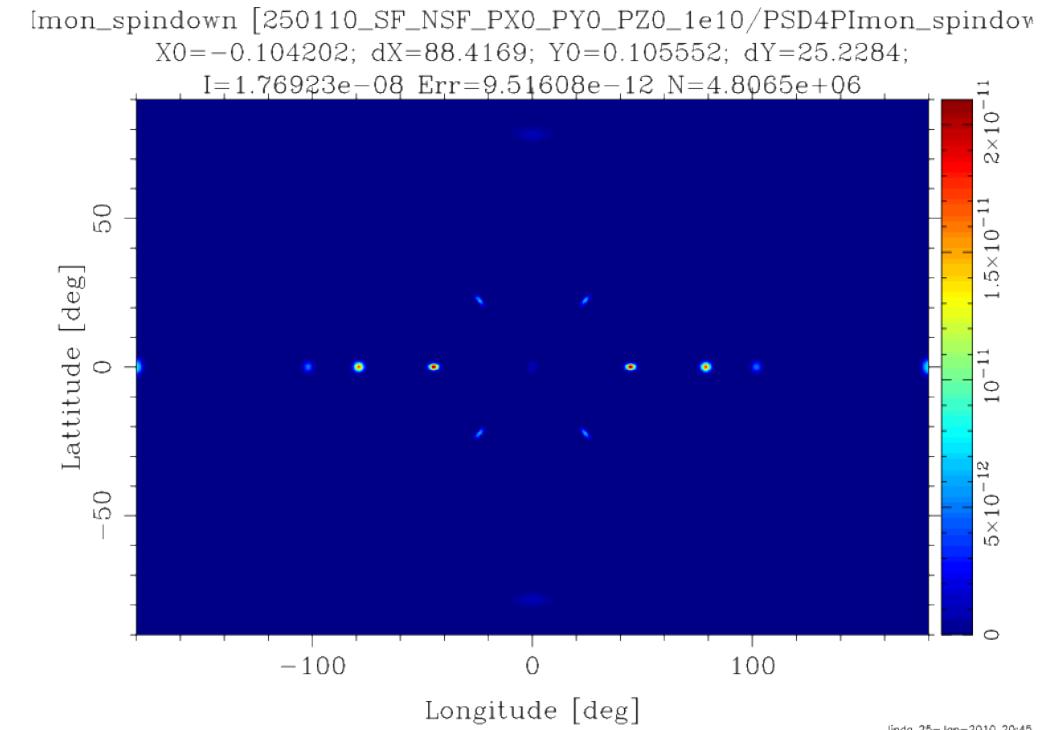
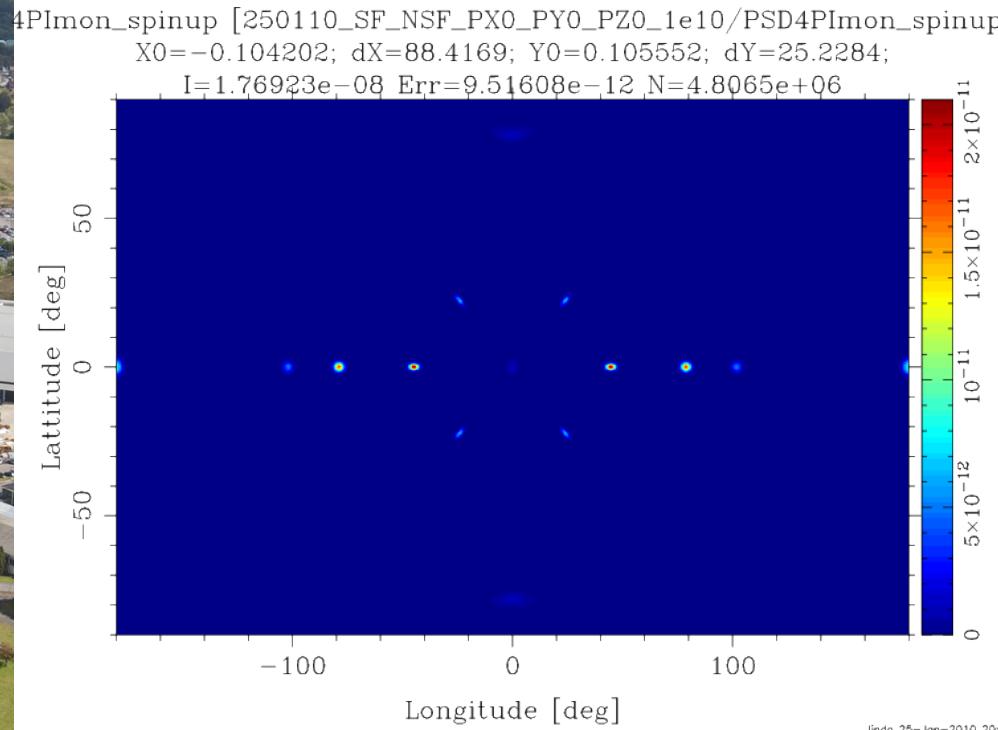
index	iontype	x	y	z	$b_{coh}[\text{fm}]$	g_S	S_x	S_y	S_z	g_L	L_x	L_y	L_z
1	Cu ²⁺	0.5	0.5	0	7.718	2	0	-0.5	0	0	0	0	0
:	:	:	:	:	:	:	:	:	:	:	:	:	:



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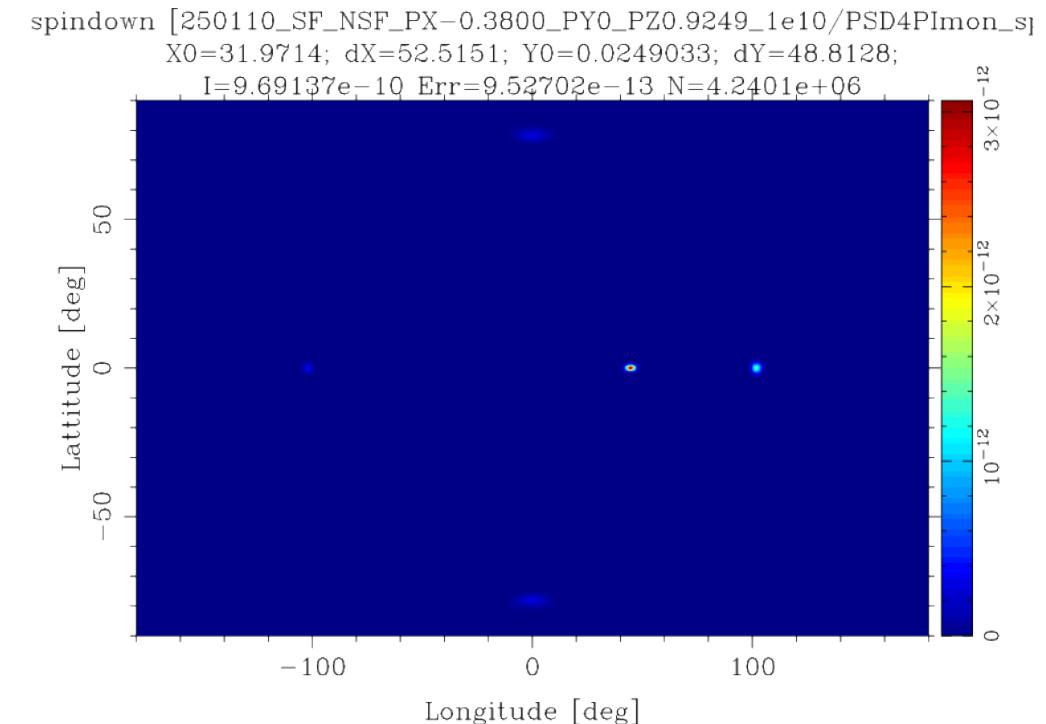
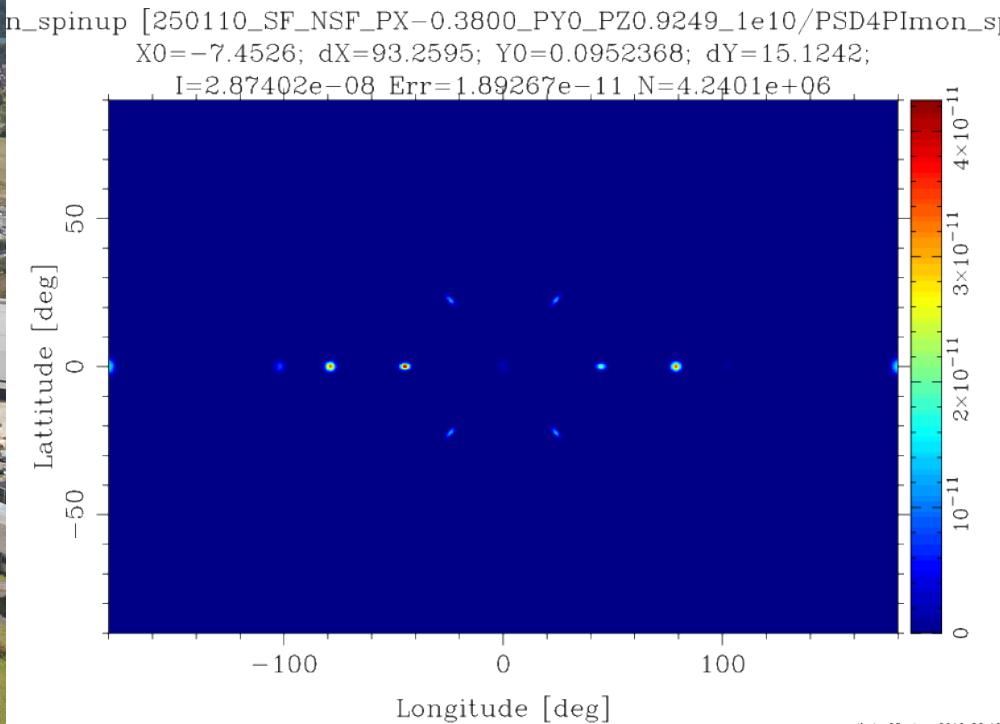
McStas component on the way

Magnetic single crystal – Unpolarized beam





Magnetic Single crystal





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SOURCE

