



Peter Willendrup

# Simulation optimisation, brilliance basics, FOM's and tools





*McStas*



2021  
*HighNESS*  
*Virtual*  
*McStas*  
*School*

# Topics

- Optimising your simulation (statistics etc.)
  - Variance reduction / biasing
- Source brilliance and brilliance transfer
- Deciding for a figure of merit
- Tools: scans, iFit and guide\_bot





2021  
HighNESS  
Virtual  
McStas  
School



# Important points to remember

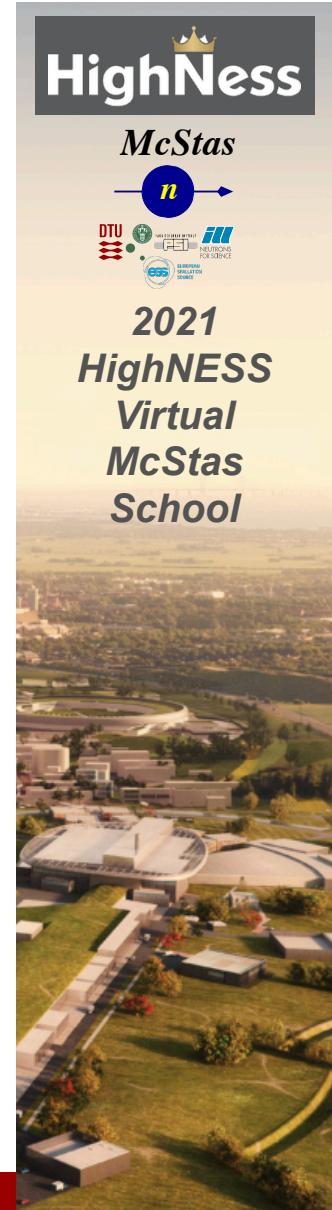
1. Your simulation will only contain elements you provided / defined
2. ... to the precision you defined
3. Answers the questions you posed
4. Background essentially only from “sample”, or sample-near objects
  - Use *concentric* geometry / Union concept for sample env
  - Source-term backgrounds are an MCNP-oriented problem





McStas  
 n  
DTU European Spallation Source

2021  
HighNESS  
Virtual  
McStas  
School



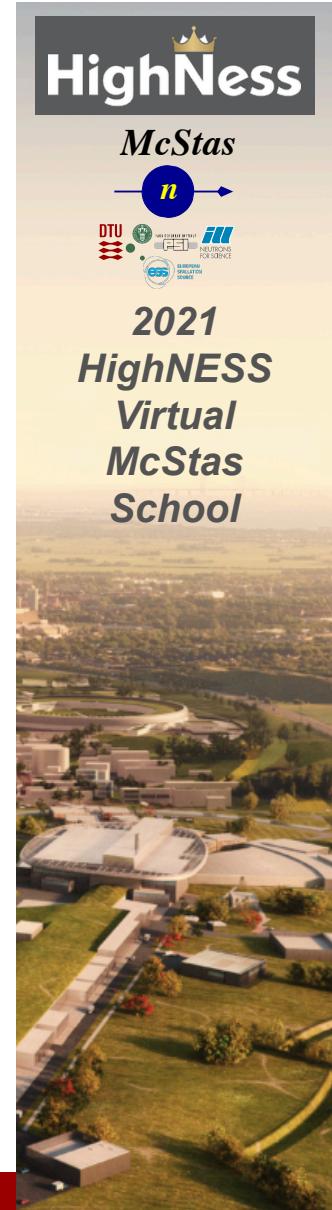
# Ensuring efficiency of the simulation is an important start...

- ◆ Apply focusing techniques
  - ◆ At the source (spatially, temporally, in wavelength...)
  - ◆ At the sample, if possible
- ◆ (carefully!) Apply SPLIT - but only if immediately followed by Monte Carlo choices, e.g. in sample
- ◆ Alternatively use MCPL o/i which allows repetition - beware of biases! Same rule of thumb in order here.





2021  
HighNESS  
Virtual  
McStas  
School



# Ensuring efficiency of the simulation is an important start...

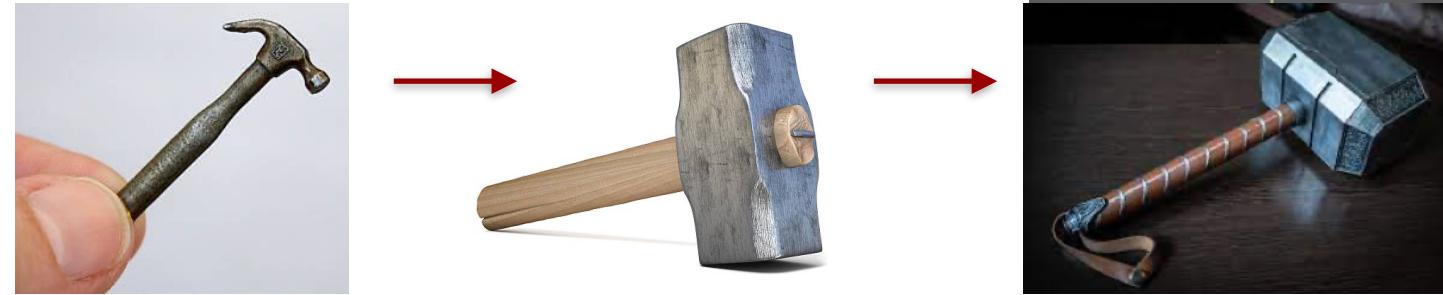
- ◆ Apply focusing techniques
  - ◆ At the source (spatially, temporally, in wavelength...)
  - ◆ At the sample, if possible
- ◆ (carefully!) Apply SPLIT - but only if immediately followed by Monte Carlo choices, e.g. in sample
- ◆ Alternatively use MCPL o/i which allows repetition - beware of biases! Same rule of thumb in order here.

**All of this can be considered “variance reduction” or biasing**



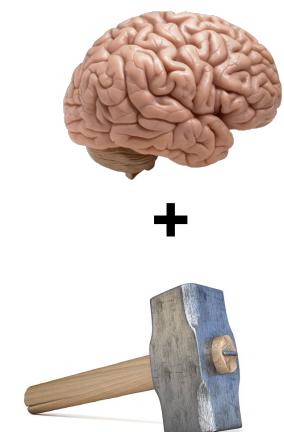


## Parallelisation for better stats, brute-force... Which hammer?



- ◆ Use **MPI** parallelisation - included in macOS install from 2.4, easy to get on Linux...
- ◆ Choice of compiler and optimisation flags can at times give ~a factor of 2 in speed, cf. clang vs. Intel C
- ◆ Think of moving to McStas 3.0 and GPU's could help you... (see Friday talk / demo)
- ◆ - **Always** consider if you are asking the right question if runtimes reach days/weeks... **Pick the right hammer!**

**Sledge-hammer / brute force!**

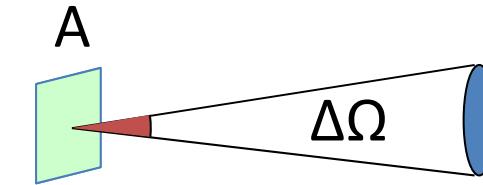




McStas



2021  
HighNESS  
Virtual  
McStas  
School



$B = N \text{ per time per } A \text{ per } \Delta\Omega$

units =  $n/s/cm^2/sr$

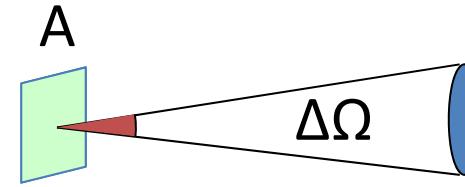




*McStas*



2021  
*HighNESS*  
*Virtual*  
*McStas*  
*School*



B is independent of distance

- property of the source

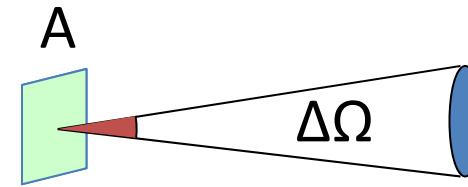




*McStas*



2021  
*HighNESS*  
*Virtual*  
*McStas*  
*School*



Brilliance/Brightness      B       $[n/s/cm^2/sr]$

Flux                           $\Psi$        $[n/s/cm^2]$

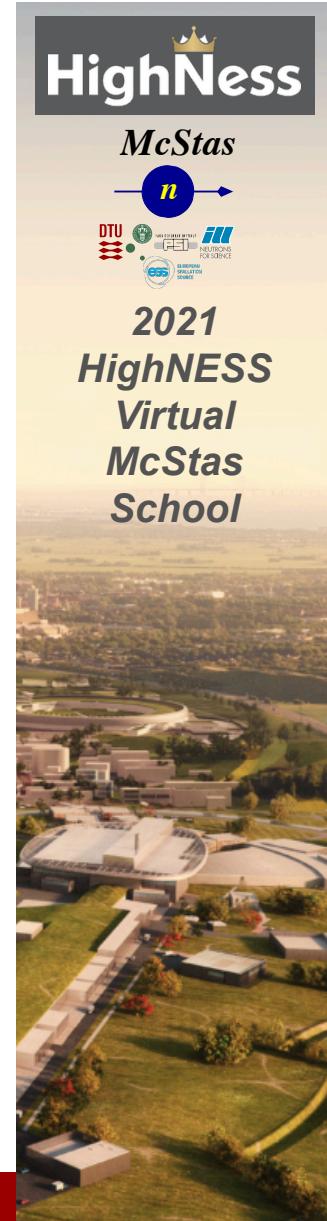




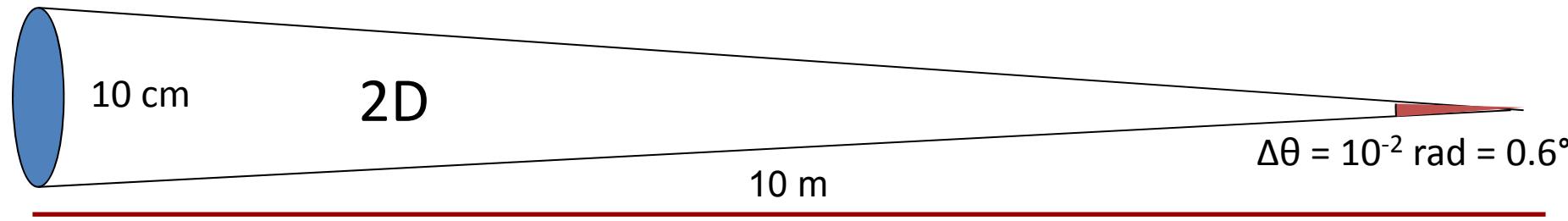
*McStas*



2021  
*HighNESS*  
Virtual  
*McStas*  
*School*



# Neutron flux - and brilliance / brightness



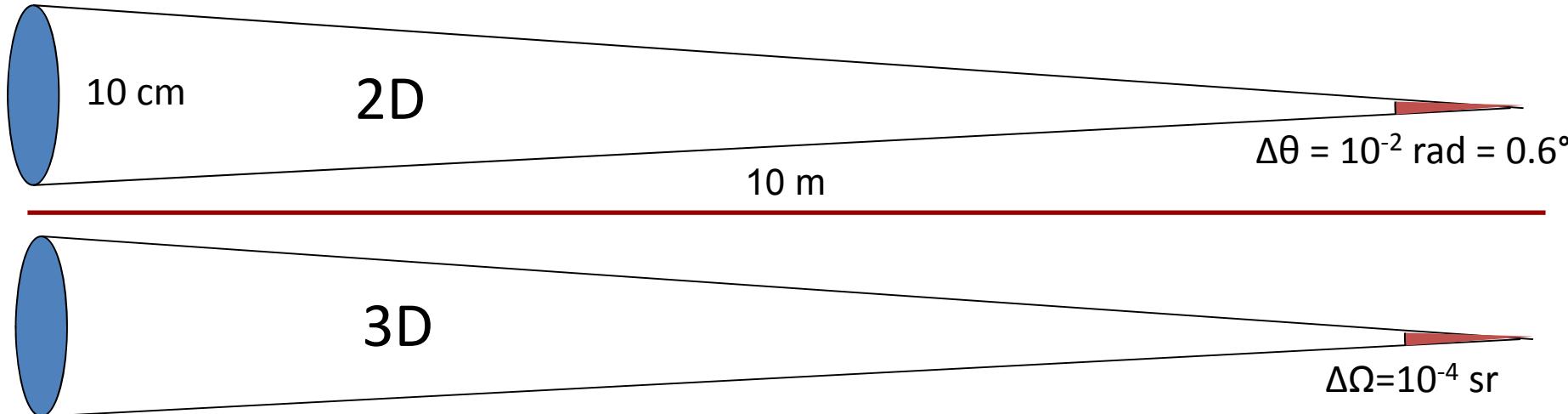


*McStas*



2021  
HighNESS  
Virtual  
McStas  
School

# Neutron flux - and brilliance / brightness



$$\text{Flux} = \text{Source Brightness} \times \text{Solid Angle}$$

$$\Phi = B \times \Delta\Omega$$



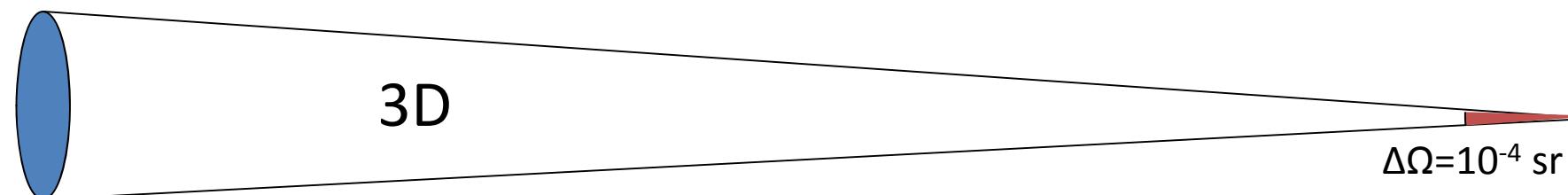
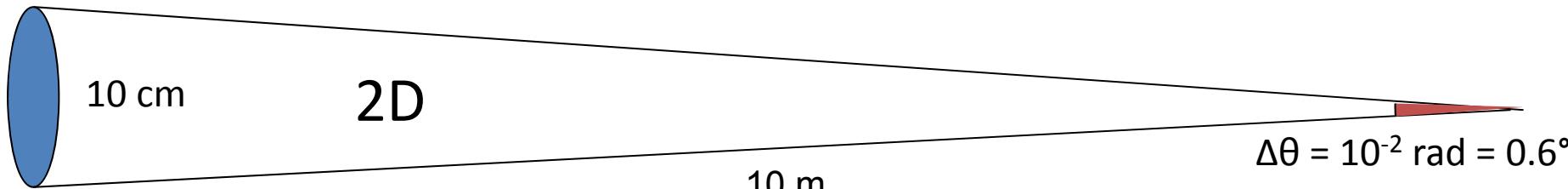
## HighNess

*McStas*



2021  
HighNESS  
Virtual  
McStas  
School

# Neutron flux - and brilliance / brightness



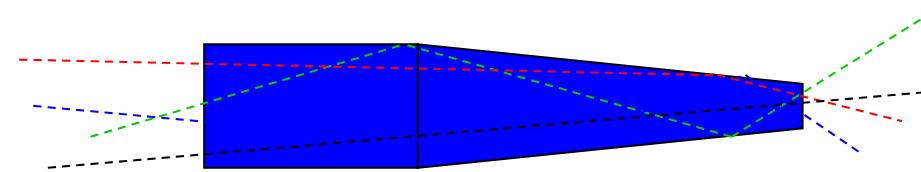
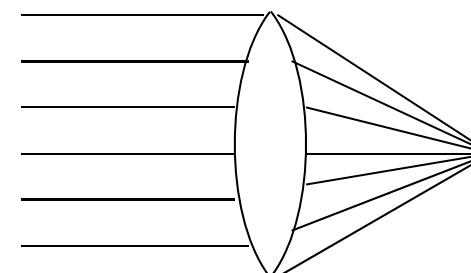
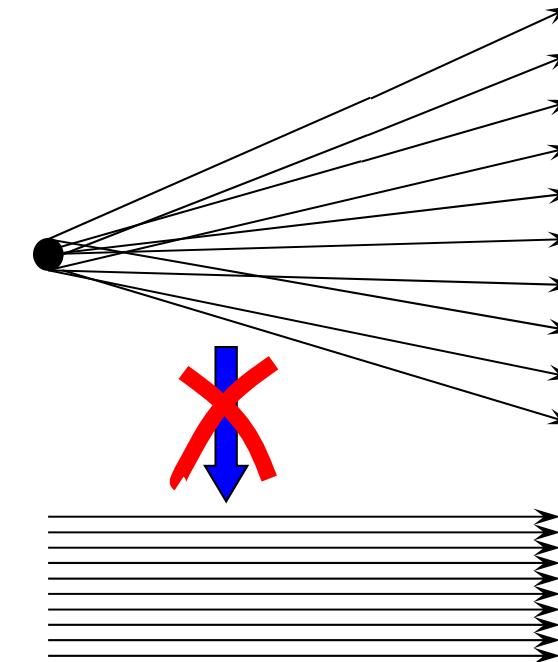
$$\text{Flux} = \text{Source Brightness} \times \text{Solid Angle}$$

$$\Phi = B \times \Delta\Omega$$



# Liouvilles Theorem

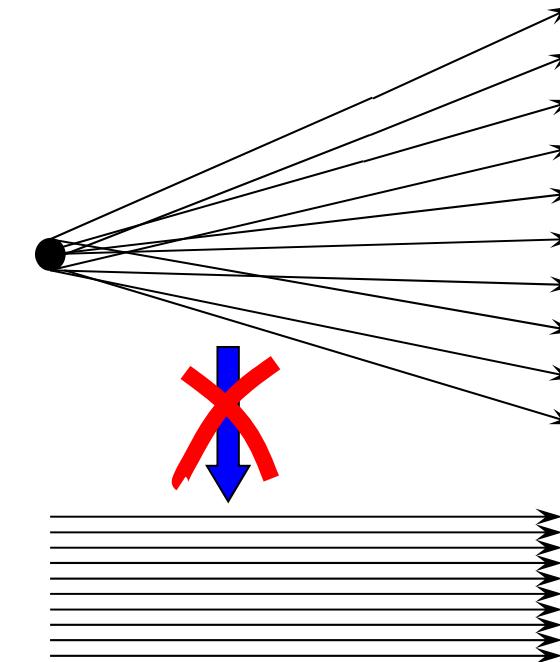
- Conservation laws:
  - neutrons can't be created from thin air
  - neither can “phase space density”
- There is no such thing as a free lunch
  - Beam manipulation transfers distribution between time, area, divergence, energy
- Most common application:
  - Focusing increases divergence
  - improve flux, lose angular resolution



Liouville theorem  
 $\rightarrow \Delta x \Delta \phi = \text{const}$

# Liouvilles Theorem

- Conservation laws:
  - neutrons can't be created from thin air
  - neither can “phase space density”
- There is no such thing as a free lunch
  - Beam manipulation transfers distribution between time, area, divergence, energy
- Most common application:
  - Focusing increases divergence
  - improve flux, lose angular resolution



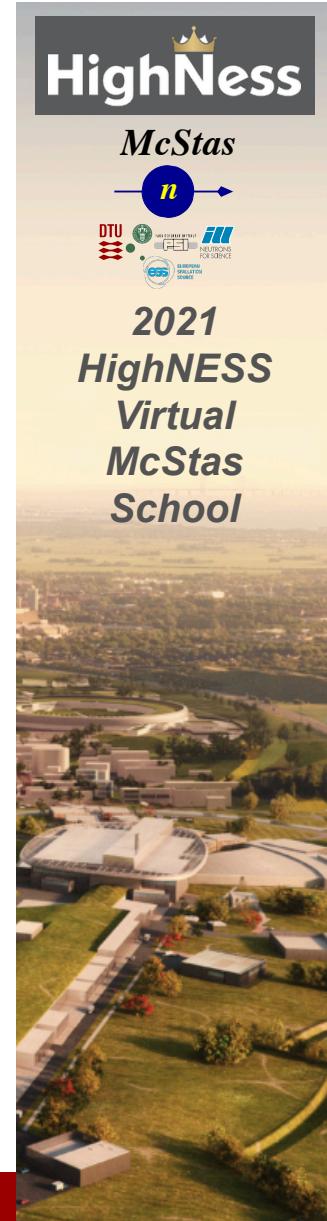
Integrated flux  $\int \Psi dA d\Omega$  can never increase



McStas

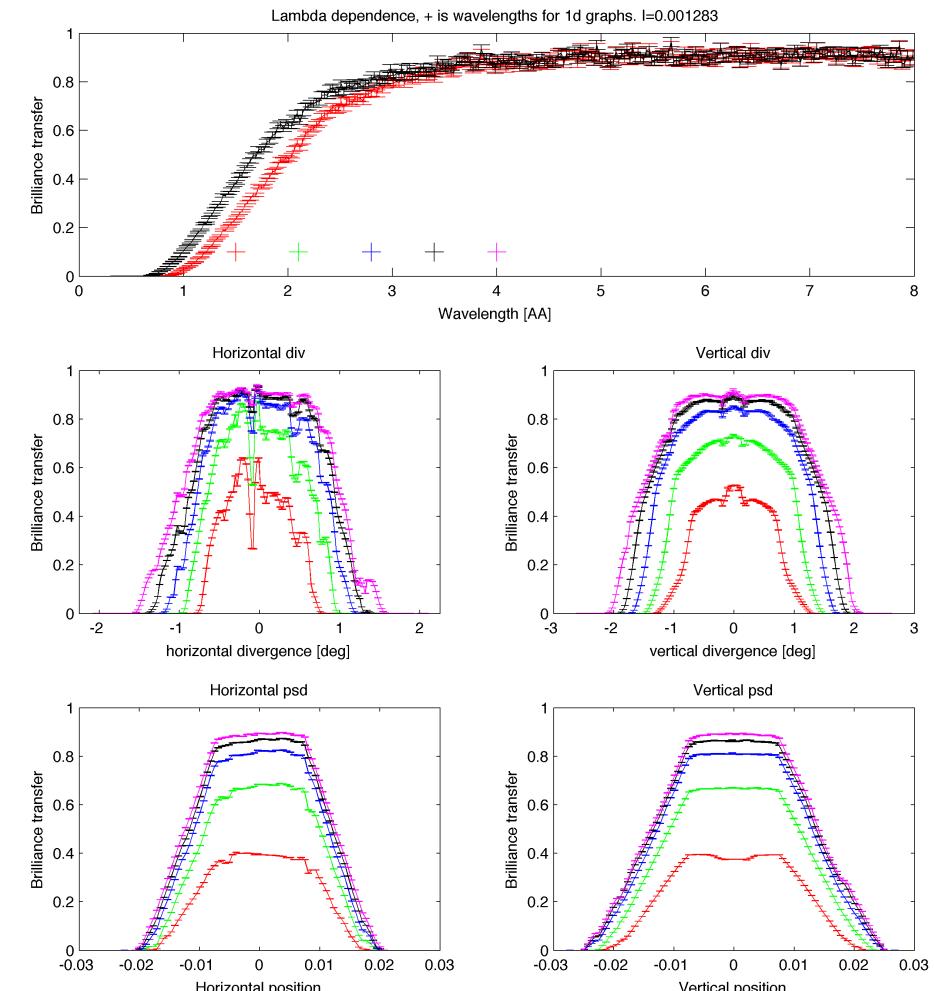
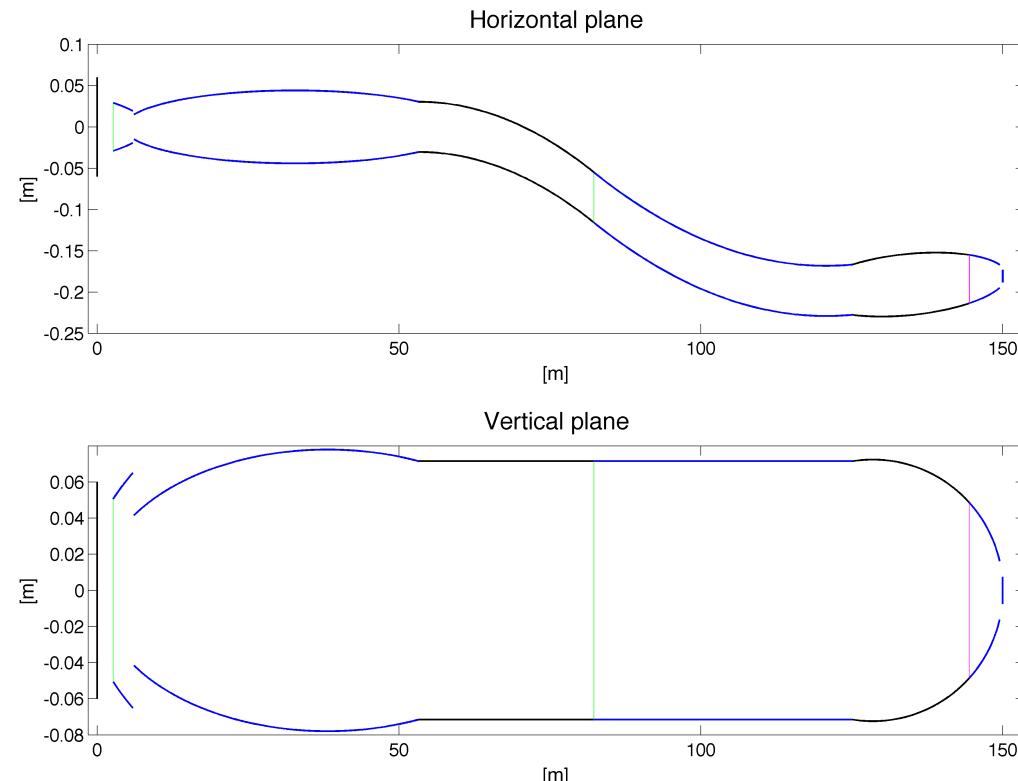


2021  
HighNESS  
Virtual  
McStas  
School



# A good optic maximises *transfer of brilliance*

- Example, elliptic guide designed by guide\_bot
- See Thursday talk by Mads Bertelsen



# Simple BT-means by McStas-code? See example folder...

- **BTsimple**, measures phase space before optic...

1.

```
/* Measure incoming phase-space */
COMPONENT BT_in = L_monitor(xwidth=0.02, yheight=0.02, filename="BT_in.dat",
                             Lmin=lambda-dlambda, Lmax=lambda+dlambda, nL=101, restore_neutron=1)
WHEN ((VertDiv <= maxvd) && (HorDiv <= maxhd)) AT (0,0,2.0) RELATIVE origin
```



# Simple BT-means by McStas-code? See example folder...

- **BTsimple**, measures phase space **before** optic...

1.

```
/* Measure incoming phase-space */  
COMPONENT BT_in = L_monitor(xwidth=0.02, yheight=0.02, filename="BT_in.dat",  
    Lmin=lambda-dlambda, Lmax=lambda+dlambda, nL=101, restore_neutron=1)  
WHEN ((VertDiv <= maxvd) && (HorDiv <= maxhd)) AT (0,0,2.0) RELATIVE origin
```

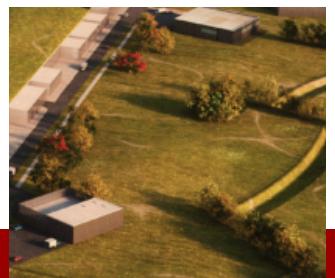
Directional range



Spatial ranges



Spectral range



# Simple BT-means by McStas-code? See example folder...

- **BTsimple**, measures phase space **before** and **after** optic...

1.

```
/* Measure incoming phase-space */
COMPONENT BT_in = L_monitor(xwidth=0.02, yheight=0.02, filename="BT_in.dat",
                             Lmin=lambda-dlambda, Lmax=lambda+dlambda, nL=101, restore_neutron=1)
WHEN ((VertDiv <= maxvd) && (HorDiv <= maxhd)) AT (0,0,2.0) RELATIVE origin
```

2.

```
/* Measure outgoing phase-space @ sample position */
COMPONENT BT_out = L_monitor(xwidth=0.02, yheight=0.02, filename="BT_out.dat",
                             Lmin=lambda-dlambda, Lmax=lambda+dlambda, nL=101, restore_neutron=1)
WHEN ((VertDiv <= maxvd) && (HorDiv <= maxhd)) AT (0,0,2.0+gL) RELATIVE guide
```

Same phase-space element  
and identical binning...



# Simple BT-means by McStas-code?

## See example folder...

- **BTsimple**, measures phase space **before** and **after** optics  
calculates transferred fraction as fct. of wavelength:

```
1. /* Measure incoming phase-space */
COMPONENT BT_in = L_monitor(xwidth=0.02, yheight=0.02, filename="BT_in.dat",
                           Lmin=lambda-dlambda, Lmax=lambda+dlambda, nL=101, restore_neutrons=0);
WHEN ((VertDiv <= maxvd) && (HorDiv <= maxhd)) AT (0,0,2.0) RELATIVE origin
```

```
2. /* Measure outgoing phase-space @ sample position */
COMPONENT BT_out = L_monitor(xwidth=0.02, yheight=0.02, filename="BT_out.dat",
                           Lmin=lambda-dlambda, Lmax=lambda+dlambda, nL=101, restore_neutrons=0);
WHEN ((VertDiv <= maxvd) && (HorDiv <= maxhd)) AT (0,0,2.0+gL) RELATIVE guide
```

- Performs piece-wise division of the bins w.  
error propagation

3.

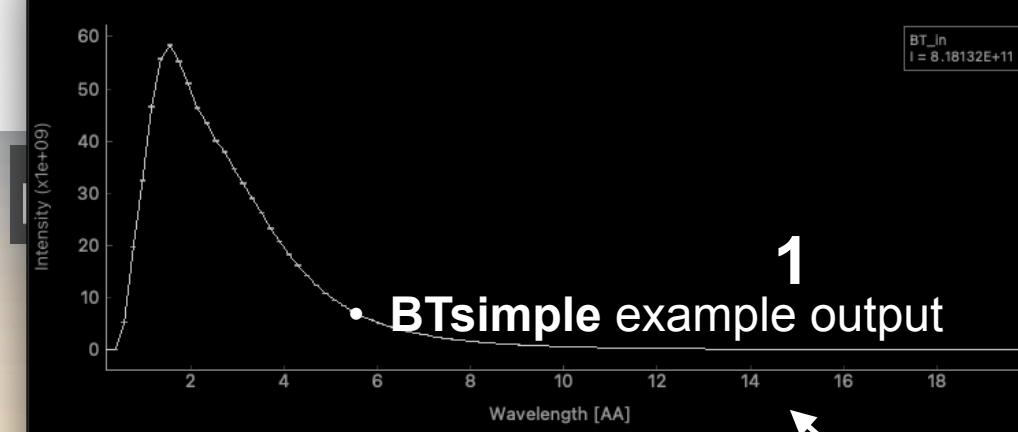
```

FINALLY
%{
/* This adds another "monitor" that measures BT_out / BT_in */
int j;
double* tmpN;
double* tmpp1;
double* tmpp2;
double* tmpd1;
double* tmpd2;
tmpN=MC_GETPAR(BT_out,L_N);
tmpp1=MC_GETPAR(BT_in,L_p);
tmpp2=MC_GETPAR(BT_out,L_p);
tmpd1=MC_GETPAR(BT_in,L_p2);
tmpd2=MC_GETPAR(BT_out,L_p2);
for (j=0;j<101;j++) {

    BT_N[j]=tmpN[j];
    if (tmpp1[j] != 0) {
        BT_p[j]=tmpp2[j]/tmpp1[j];
    } else {
        BT_p[j]=0;
    }
    if ((tmpp1[j] != 0) && (tmpp2[j] != 0)) {
        BT_p2[j]=sqrt((tmpd1[j]/tmpp1[j])*(tmpd1[j]/tmpp1[j])
                      + (tmpd2[j]/tmpp2[j])*(tmpd2[j]/tmpp2[j]));
    } else
        BT_p2[j]=0;
}
// This set of defines is to avoid getting a '.' in the component name
#ifndef NAME_CURRENT_COMP
#define NAME_CURRENT_COMP
#endif
#define NAME_CURRENT_COMP "BTransfer"
#endif
DETECTOR_OUT_1D(
    "Brilliance transfer",
    "Wavelength [AA]",
    "BT",
    "L", lambda-dlambda, lambda+dlambda, 101,
    &BT_N[0],&BT_p[0],&BT_p2[0],
    "Brilliance_transfer.dat");
%}

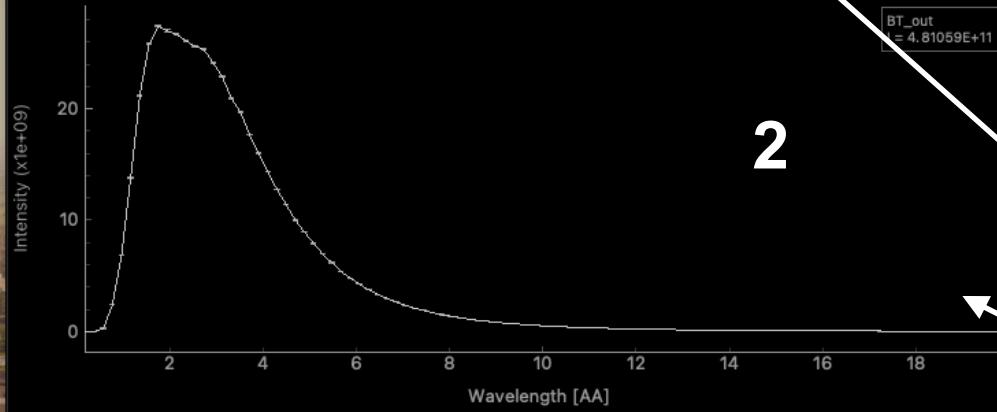
```



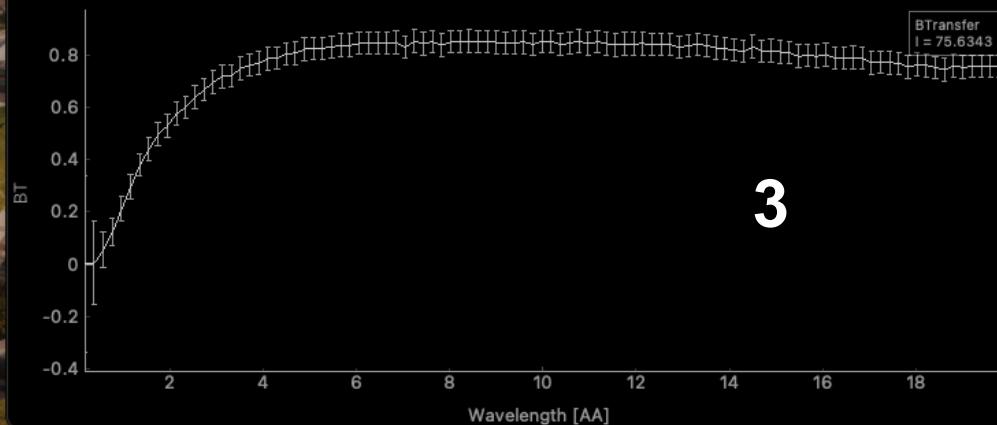


• BTsimple example output

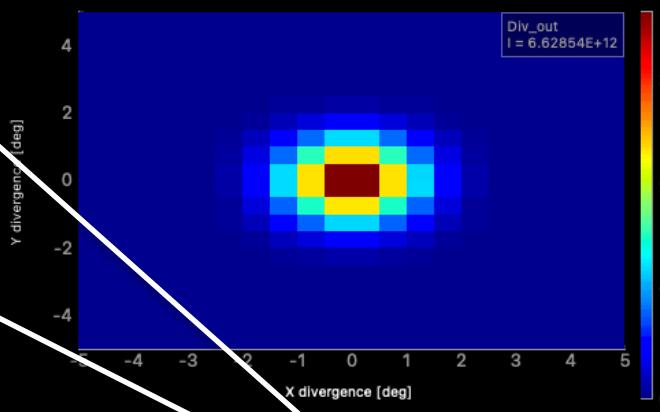
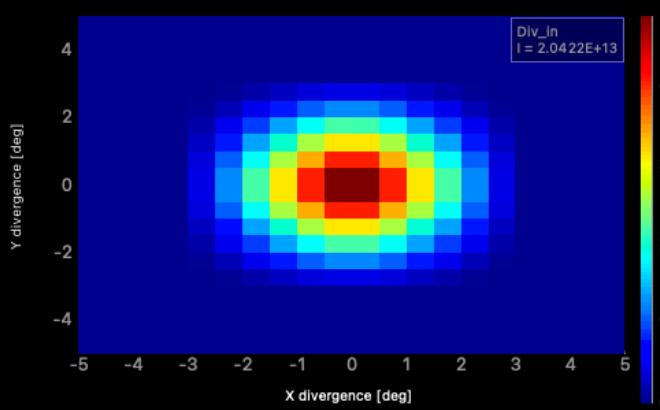
1



2



3



# What to optimise? Figure of merit requires thought...



McStas



2021

HighNESS  
Virtual  
McStas  
School

- Brilliance-transfer is probably a good quantity to think of, yet...
- Also, a case-specific FOM should be chosen
  - Usually not a matter of simply maximising SP flux...
  - Depends strongly on the science to be done
    - Typical sample size, needed q and E resolution etc.
    - Relevant wavelength-band, needed dynamical range, needed resolution
    - Cost (e.g. in the form of shielding requirements, guide coatings)
- See parallel sessions!



# FOM examples for different types of instruments

STS04-41-TR0002, R00

**High****Mc****n****20****Highl****Virt****MCS****Sch**

**Table 7.2 – Metrics proposed by the individual working groups**

Instrument group	Flux metric	Shape metric
Small angle neutron scattering	$\max \left( \int_{1.5\text{\AA}}^{20\text{\AA}} IF(\lambda) \lambda^{2-3} d\lambda \right)$	N/A
Reflectometry	$\max \left( \int_{3\text{\AA}}^{15(20)\text{\AA}} IF(\lambda) \lambda^4 d\lambda \right)$	N/A
Spin-Echo	$\max \left( \int_{4\text{\AA}}^{20\text{\AA}} IF(\lambda) \lambda^{2-3} d\lambda \right)$	N/A
Spectroscopy	$\max \left( \int_{1\text{\AA}}^{10\text{\AA}} PF(\lambda) \lambda^0 d\lambda \right)$	$\min \left( \int_{1\text{\AA}}^{10\text{\AA}} \left  \frac{dPF(\lambda)}{d\lambda} \right  d\lambda \right)$
Nuclear (classical) diffraction	$\max \left( \int_{0.5(0.2)\text{\AA}}^{4\text{\AA}} PF(\lambda) \lambda^0 d\lambda \right)$	$\min \left( \int_{0.5(0.2)\text{\AA}}^{4\text{\AA}} \left  \frac{dPF(\lambda)}{d\lambda} \right  d\lambda \right)$
Magnetic diffraction	$\max \left( \int_{1\text{\AA}}^{10\text{\AA}} PF(\lambda) \lambda^0 d\lambda \right)$	$\min \left( \int_{1\text{\AA}}^{10\text{\AA}} \left  \frac{dPF(\lambda)}{d\lambda} \right  d\lambda \right)$

Here  $IF(\lambda)$  is defined as the pulse-integrated flux and  $PF(\lambda)$  is the pulse-peak flux for a

STS04-41-TR0002, R00

**Long-Pulse Neutron Instrumentation Workshop,**  
**August 26-28, 2009**

**Report**

R. K. Crawford (editor), M. Arai, C. Carlile, L. Chapon, G. Granroth, S. Langridge,  
 K. Lefmann, F. Mezei, M. Monkenbusch, G. Muhrer, A. Wiedenmann

Rev. 00 - August 2010

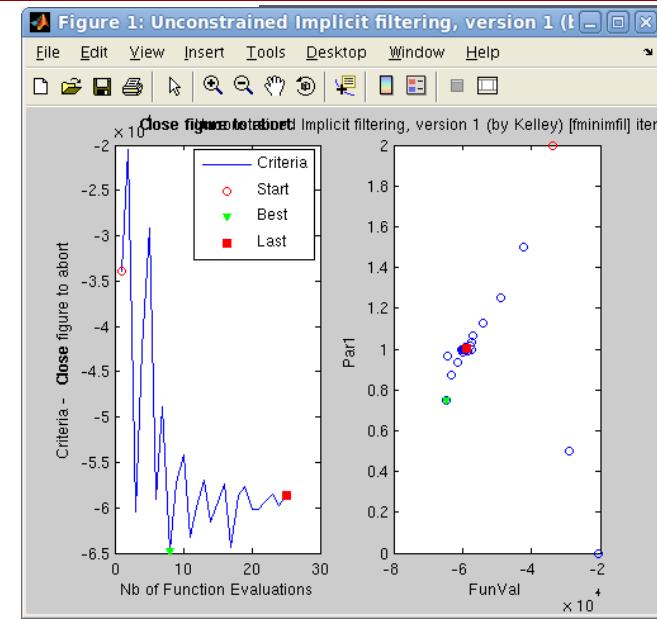
Prepared by  
 OAK RIDGE NATIONAL LABORATORY  
 P.O. Box 2008  
 Oak Ridge, Tennessee 37831-6285  
 managed by  
 UT-Battelle, LLC  
 for the  
 U.S. DEPARTMENT OF ENERGY  
 under contract DE-AC05-00OR22

# Parameter-variation

- mcrun and mcgui provide
  - Simple equidistant line-scans or colinear scans  
 $\text{par}=\text{a,b -N k.}$  /  $\text{par1}=\text{a,b par2=c,d -Nk}$
- mcrun further provides
  - -L list mode (can be non-equidistant, user chooses order, still a form of scan)  
 $\text{par1}=\text{a,b,c,d,e,f par2=g,h,i,j,k,l}$
- Run your simulations via iFit <http://ifit.mccode.org> - see <http://ifit.mccode.org/McStas.html>
  - McStas simulation becomes an **object function**, monitor(s) an **optimisation criterion**
  - Includes a host of different optimisers, e.g. particle swarms in parameter-space
  - Matlab-based, perform calculations based on monitor outputs (!! use Matlab <= 2017b !!)
  - Can work as a recompiled binary, but not as stable as a pure Matlab
  - Use official distribution package from <http://ifit.mccode.org/Downloads/iFit.zip>, GitHub code is too 'bleeding edge'



guide\_bot tool is built on iFit, see Thursday talk. Mads recommends Matlab 2012 and iFit 1.3...



iFit





*McStas*



2021  
*HighNESS*  
*Virtual*  
*McStas*  
*School*



# By now you have been presented with most of the bricks...

- Next, think of how to assemble them to solve your specific problem...

