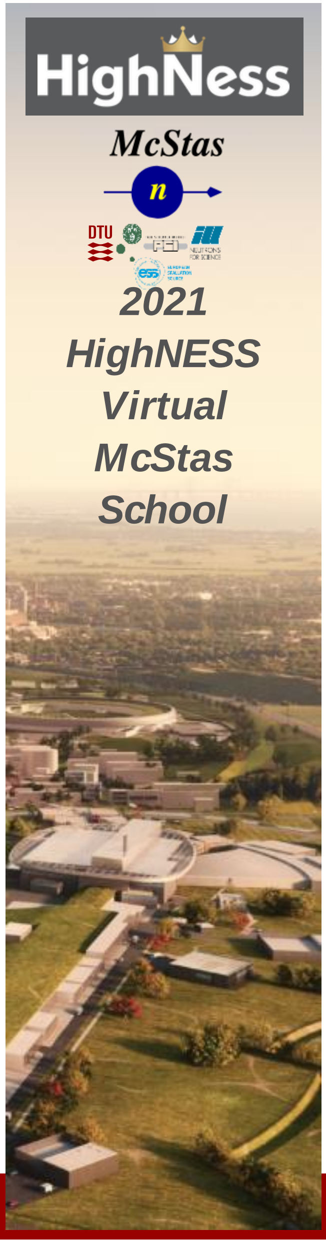
HighNESS is funded by the European Framework for Research and Innovation Horizon 2020, under grant agreement 951782

Erik Knudsen, DTU Physics

Sources and Monitors part 2.

Sources: Source model overview



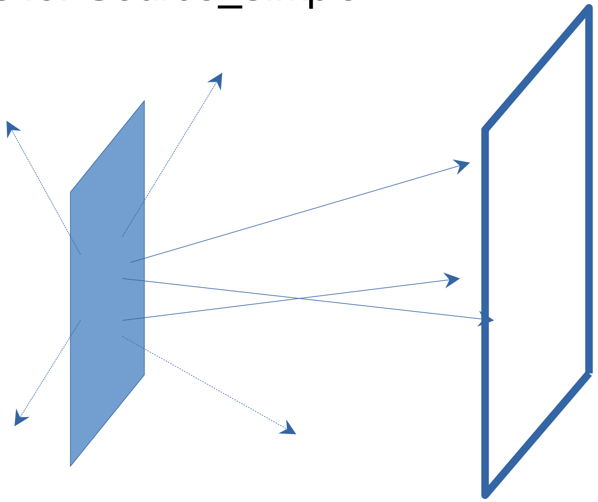
- ***Mathematical**:*
  - *Source_simple.comp*
  - *Source_div.comp*
- ***Pulsed sources**:*
  - *ESS_butterfly.comp*
  - *ESS_moderator.comp*
  - *Moderator.comp*
  - *SNS_source.comp (*)*
  - *SNS_source_analytic (*)*
  - *ViewModISIS (*)*
  - *ISIS_moderator.comp (*)*
- ***Reactors** :*
  - *Source_Maxwell_3.comp*
  - *Source_gen.comp*
  - *Source_gen4.comp*
  - *Source_multi_surfaces.comp (*)*
- *I/O mechanisms:*
- ***MCPL_input/output.comp***
  - *Virtual_input/output.comp*
  - *Virtual_mcnp_ss_input/output.comp*
  - *Virtual_tripoli4_input/output.comp*
  - *Vitess_input/output.comp*

Sources: Source_Maxwell_3

```
COMPONENT source = Source_Maxwell_3(yheight=0.156, xwidth=0.126,
                   Lmin=0.1, Lmax=9.0, dist=1.5, focus_xw = 0.025, focus_yh = 0.12,
                   T1=150.42, I1=3.67E11, T2=38.74, I2=3.64E11, T3=14.84, I3=0.95E11)
```

Parameters from the PSI cold source

Initial position and direction: as for Source_simple



McStas

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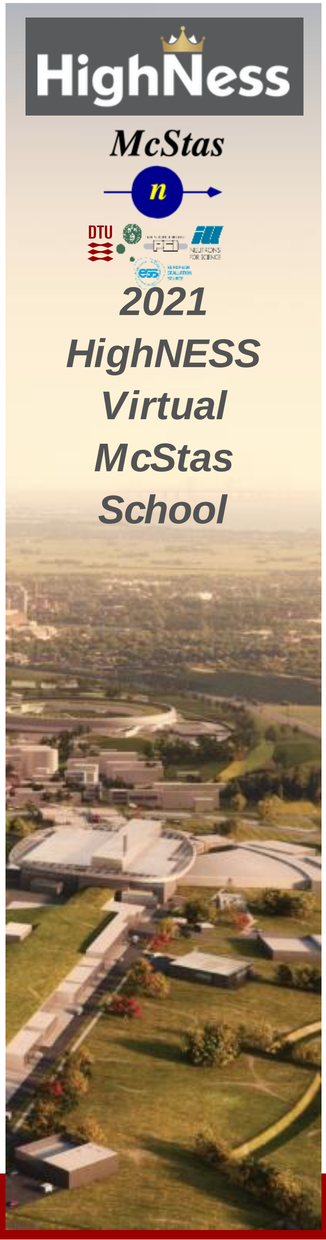


Sources: Source_Maxwell_3

```
COMPONENT source = Source_Maxwell_3(yheight=0.156, xwidth=0.126,
          Lmin=0.1, Lmax=9.0, dist=1.5, focus_xw = 0.025, focus_yh = 0.12,
          T1=150.42, I1=3.67E11, T2=38.74, I2=3.64E11, T3=14.84, I3=0.95E11)
```

Parameters from the PSI cold source

Intensity at a given wavelength drawn from a sum of (up to) 3 normalized Maxwellian distributions:

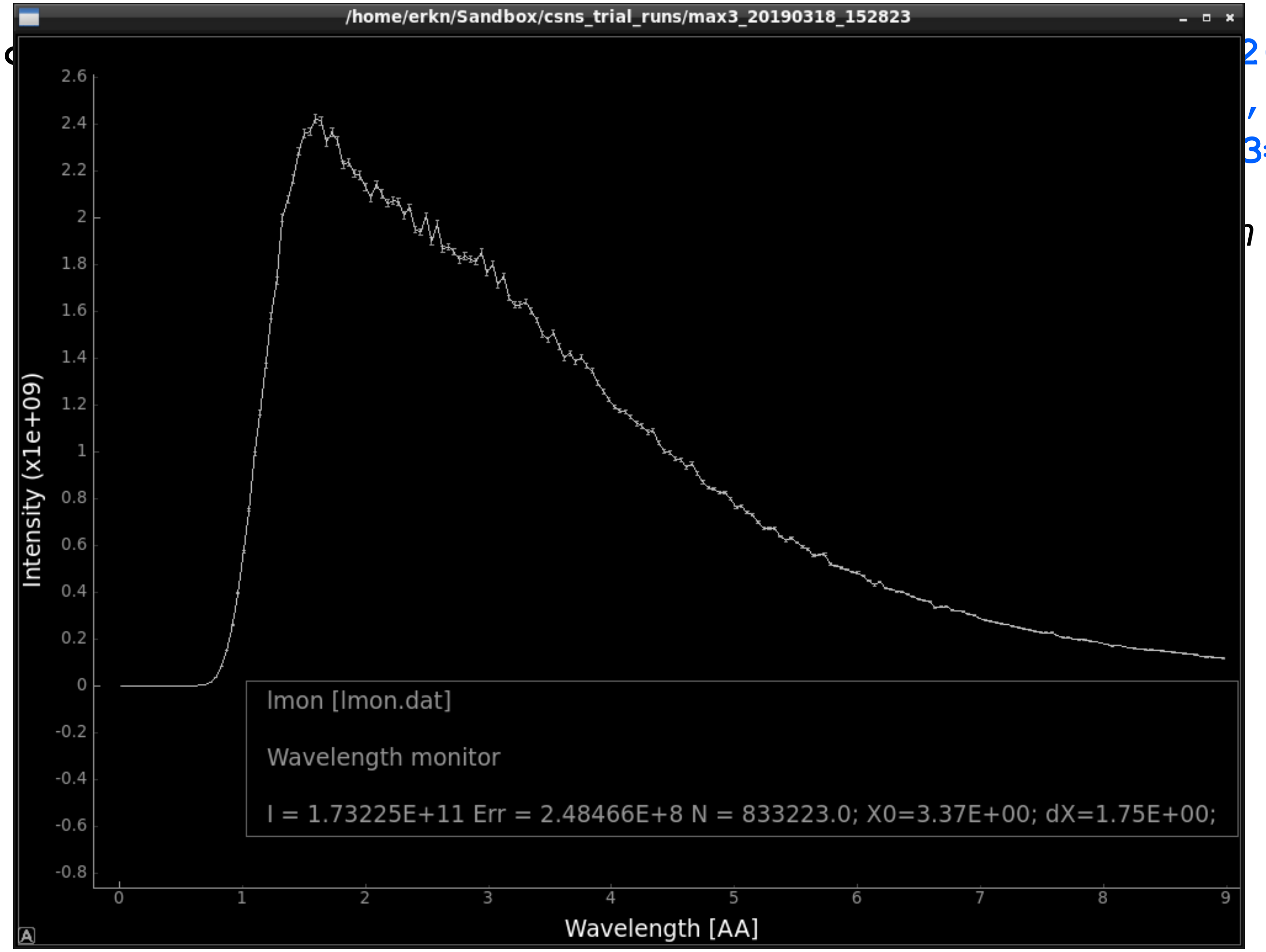
$$I(\lambda) = \sum I_i M(\lambda, T_i); \qquad M(\lambda, T_i) = 2\alpha^2 exp\left(\frac{-\alpha}{\lambda^2}\right)/\lambda^5\ ;$$

$$\alpha = 949.0K\,AA^2/T_i$$

Sources: Source_Maxwell_3

```
COMPONENT sc                                                    26,
                                               , focus_yh = 0.12,
                                               3=14.84, I3=0.95E11)
```

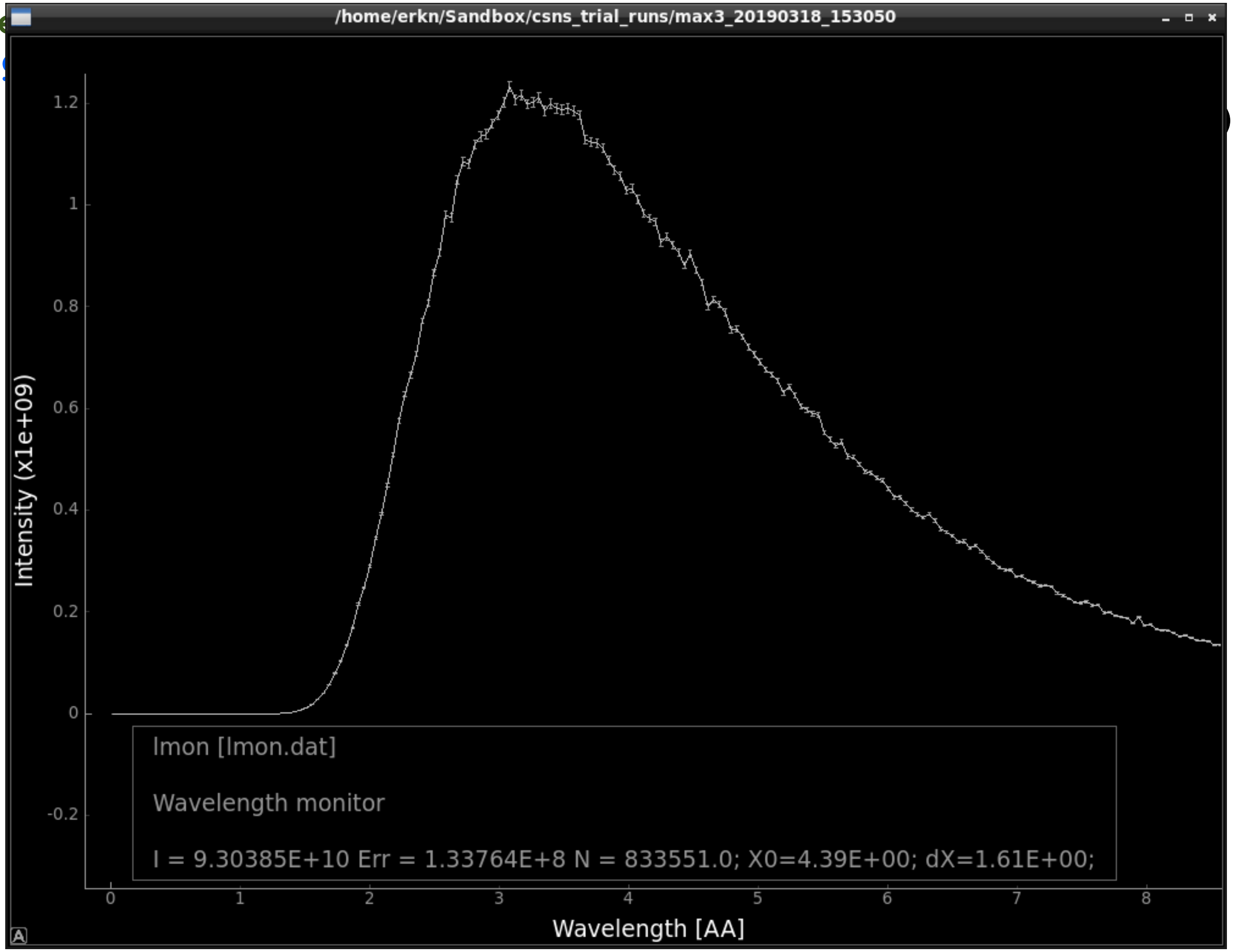
n the PSI cold source



Sources: Source_Maxwell_3

```
COMPONENT source = Source_Maxwe
              Lmin=0.1, Lmax=
              T1=150.42, I1=3
```

Just for fun – let's see what happens if we remove the fast peak…



Input parameters

Parameters in **boldface** are required; the others are optional.

Name	Unit	Description	Default
size	m	Edge of cube shaped source (for backward compatibility)	0
yheight	m	Height of rectangular source	0
xwidth	m	Width of rectangular source	0
Lmin	AA	Lower edge of lambda distribution	
Lmax	AA	Upper edge of lambda distribution	
dist	m	Distance from source to focusing rectangle; at (0,0,dist)	
focus_xw	m	Width of focusing rectangle	
focus_yh	m	Height of focusing rectangle	
T1	K	1st temperature of thermal distribution	
T2	K	2nd temperature of thermal distribution	300
T3	K	3nd temperature of - - -	300
I1	1/(cm**2*st)	flux, 1 (in flux units, see above)	
I2	1/(cm**2*st)	flux, 2 (in flux units, see above)	0
I3	1/(cm**2*st)	flux, 3 - - -	0
target_index	1	relative index of component to focus at, e.g. next is +1 this is used to compute 'dist' automatically.	+1
lambda0	AA	Mean wavelength of neutrons.	0
dlambda	AA	Wavelength spread of neutrons.	0

Sources: Source_gen (Source_gen4)

```
COMPONENT source = Source_gen(yheight=0.156, xwidth=0.126,
                Lmin=0.1, Lmax=9.0, dist=1.5, focus_xw = 0.025, focus_yh = 0.12,
                T1=150.42, I1=3.67E11, T2=38.74, I2=3.64E11, T3=14.84, I3=0.95E11)
```

Almost the same as Source_Maxwell_3: but with optional flux-files as input.

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MCPL_input/output

HighNess McStas 2021 HighNESS Virtual McStas School

Reads/writes events directly from MCPL-format files:

“T. Kittelmann et. al., “”, J. Phys. Comp., 2017

```
COMPONENT vout = MCPL_output(filename=”voutput.mcpl”,
        doubleprec=1,polarisationuse=1,verbose=1)
AT (Xout,Yout,Zout) RELATIVE PREVIOUS

COMPONENT vin = MCPL_input(filename=”voutput.mcpl”,
        polarisationuse=1,verbose=1)
AT (Xin,Yin,Zin) RELATIVE PREVIOUS
```

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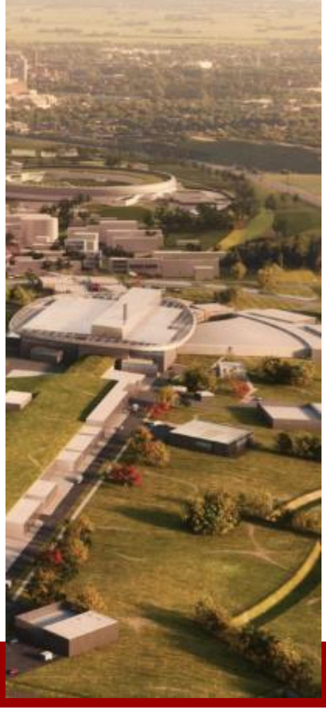


Pulsed sources:

Simplest case:

Use a continuous source!

Model a source with given wavelength and spatial distribution

and

… an infinitely short pulse length. I.e. ***t* = *0*** for all neutron rays.

```
COMPONENT src = Source_simple(
        radius=0.05, lambda0=2.5, dlambda=1.5,
        focus_xw=0.1, focus_yh=0.1, dist=5 )
AT(0,0,0) RELATIVE origin
EXTEND
%{
        t=0;
%}
```

Pulsed sources:

Simplest case:

Use a continuous source!

Model a source with given wavelength and spatial distribution

and

… an infinite … tron rays.

```
COMPONENT
        rad… …5, dlambda=1.5,
        focu… …1, focus_yh=0.1, dist=5 )
AT(0,0,0) RELATIVE origin
EXTEND
%{
        t=0;
%}
```

Or: Use a chopper
(see later)

Pulsed Sources: Moderator

A flat pulsed source with uniform energy spectrum:

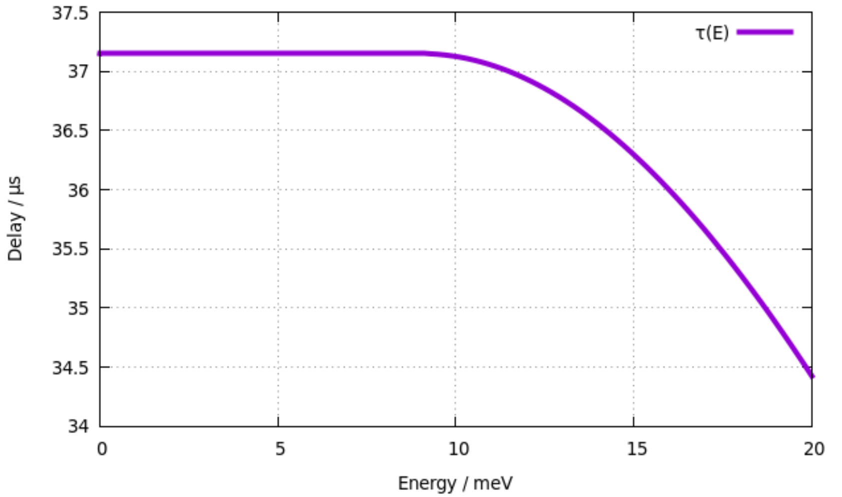
$$x \in U\left[-\frac{xwidth}{2}, \frac{xwidth}{2}\right]\ y \in U\left[-\frac{yheight}{2}, \frac{yheight}{2}\right]$$

$$|v| = f(\lambda)\,; \lambda \in U[L_{min} L_{max}]$$

Time structure is given by energy dependent probability density function:

$$f_t = \frac{1}{\tau}\, exp\left(-\frac{t}{\tau}\right)$$

$$\tau = \begin{cases} t_0; & E < E_c \\ t_0\left(\dfrac{1}{1+\dfrac{(E-E_c)}{\gamma}}\right); & E \geq Ec \end{cases}$$



Pulsed Sources: ESS_butterfly

- Analytic fits to MCNP-generated files.
- Specialized fits to each beamport.
- Fast and reasonably accurate.

Pulsed Sources: ESS_butterfly

Input parameters

Parameters in **boldface** are required; the others are optional.

Name	Unit	Description	Default
sector	str	Defines the 'sector' of your instrument position. Valid values are "N","S","E" and "W"	"N"
beamline	1	Defines the 'beamline number' of your instrument position. Valid values are 1..10 or 1..11 depending on sector	1
yheight	m	Defines the moderator height. Valid values are 0.03 m and 0.06 m	0.03
cold_frac	1	Defines the statistical fraction of events emitted from the cold part of the moderator	0.5
target_index	1	Relative index of component to focus at, e.g. next is +1 this is used to compute 'dist' automatically.	0
dist	m	Distance from origin to focusing rectangle; at (0,0,dist) - alternatively use target_index	0
focus_xw	m	Width of focusing rectangle	0
focus_yh	m	Height of focusing rectangle	0
c_performance	1	Cold brilliance scalar performance multiplicator c_performance > 0	1
t_performance	1	Thermal brilliance scalar performance multiplicator t_performance > 0	1
Lmin	AA	Minimum wavelength simulated	
Lmax	AA	Maximum wavelength simulated	
tmax_multiplier	1	Defined maximum emission time at moderator, tmax= tmax_multiplier * ESS_PULSE_DURATION.	3
n_pulses	1	Number of pulses simulated. 0 and 1 creates one pulse.	1
acc_power	MW	Accelerator power in MW	5
tfocus_dist	m	Position of time focusing window along z axis	0
tfocus_time	s	Time position of time focusing window	0
tfocus_width	s	Time width of time focusing window	0

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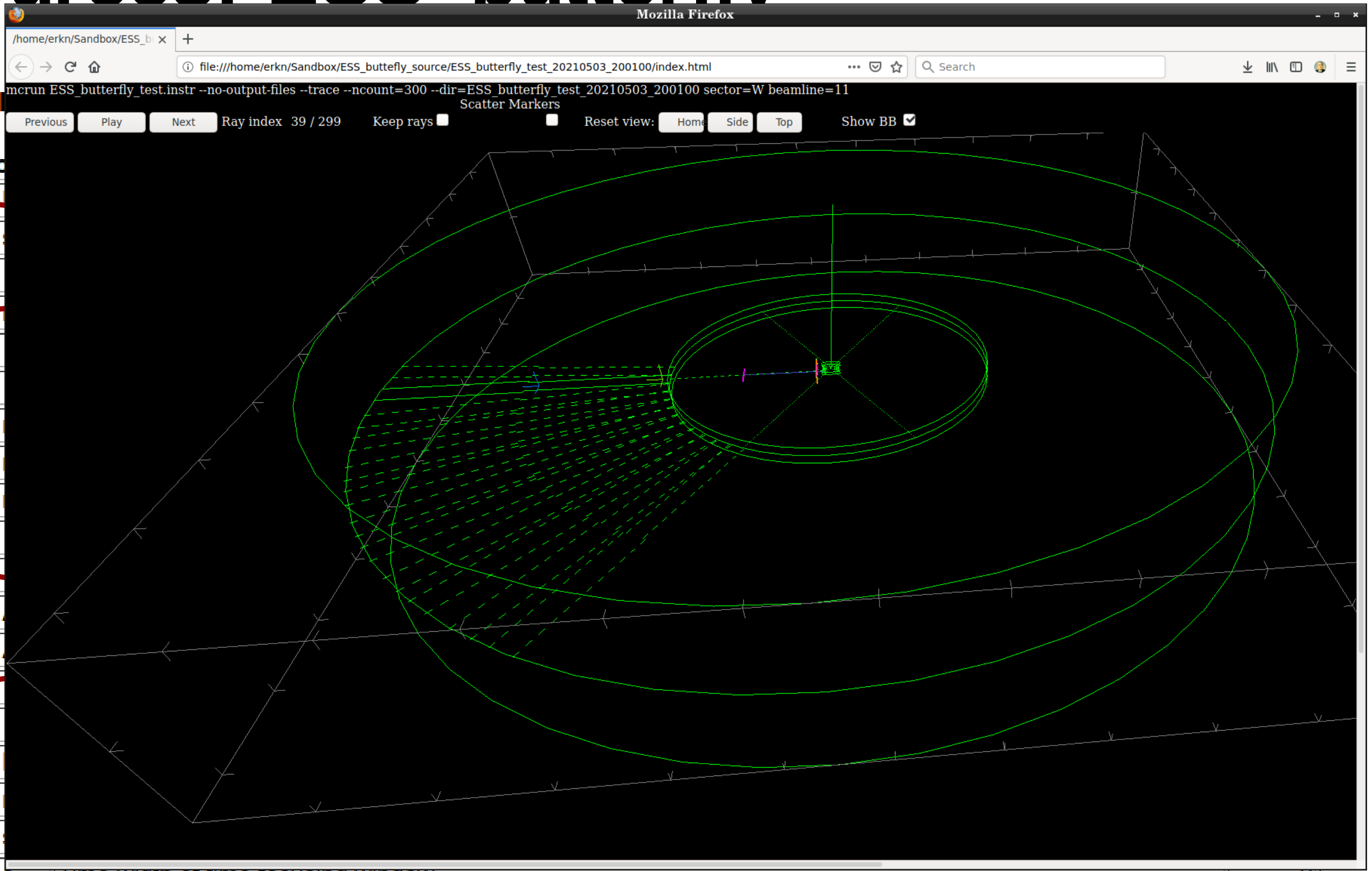
Pulsed Sources: ESS_butterfly

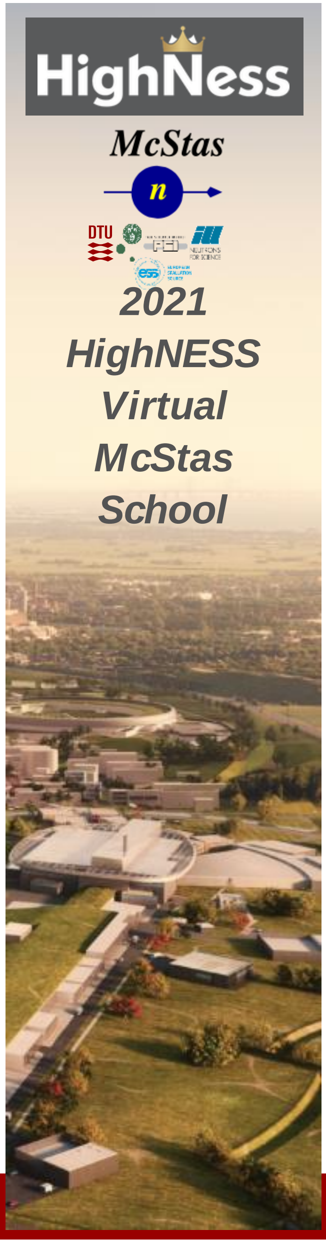
"W" - 11

Input para

Parameters in bo

Name			
sector			
beamline			
yheight			
cold_frac			
target_index			
dist			
focus_xw			
focus_yh			
c_performance			
t_performance			
Lmin			
Lmax			
tmax_multiplier			
n_pulses			
acc_power			
tfocus_dist			
tfocus_time			
tfocus_width	s	Time width of time focusing window	0





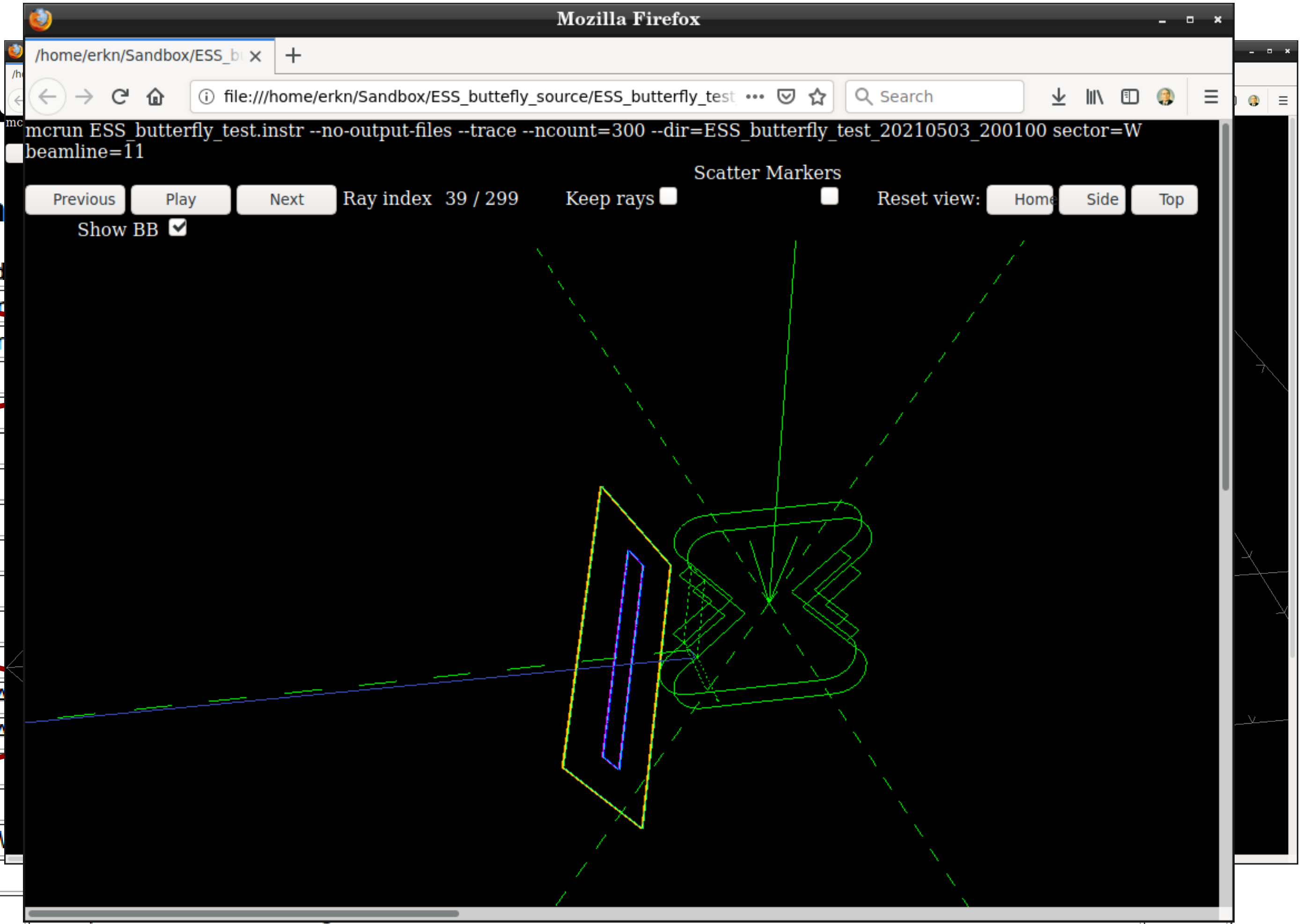
Pulsed Sou

"W" - 11

Input param

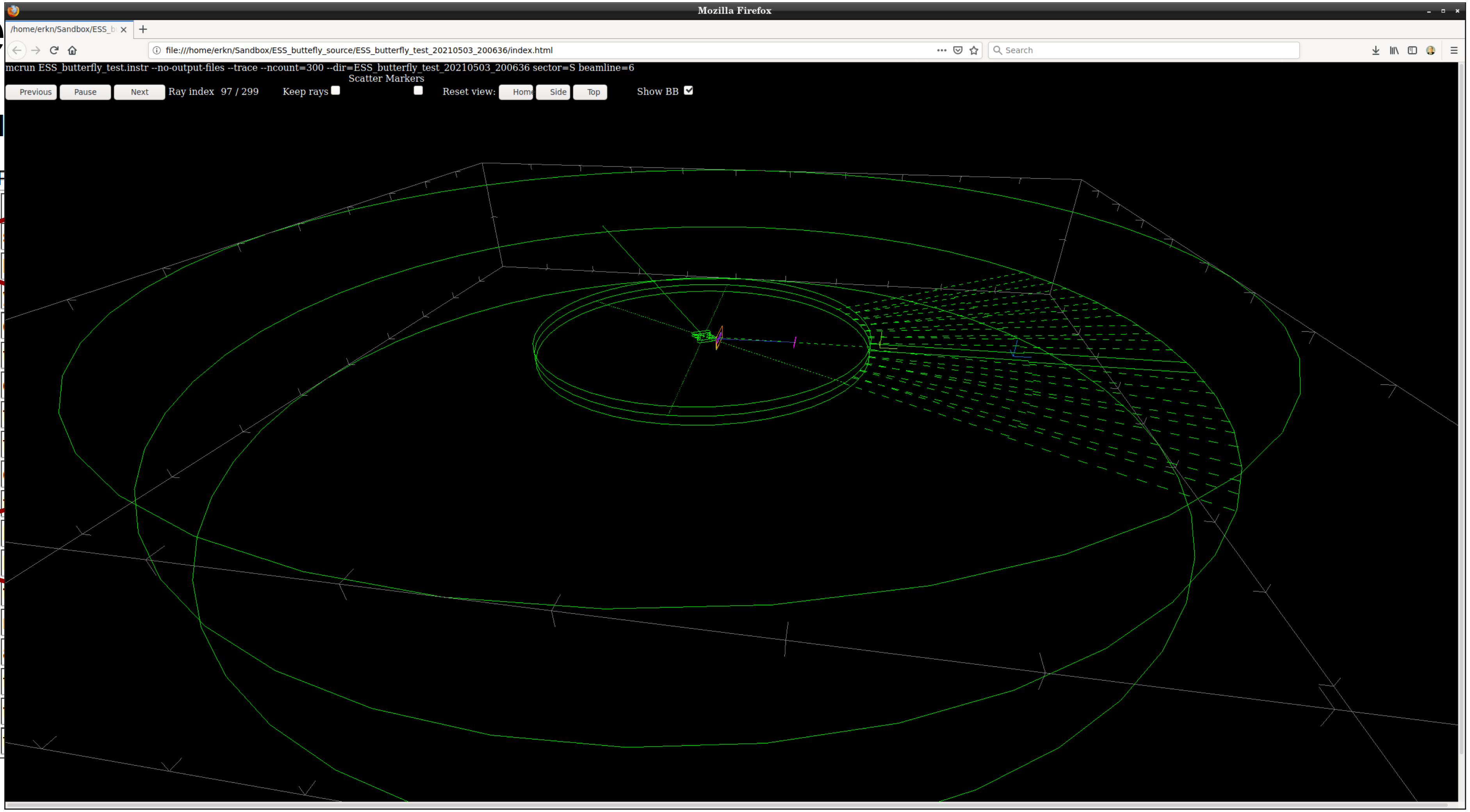
Parameters in bold

Name	Ur		
sector	str		
beamline	1		
yheight	m		
cold_frac	1		
target_index	1		
dist	m		
focus_xw	m		
focus_yh	m		
c_performance	1		
t_performance	1		
Lmin	AA		
Lmax	AA		
tmax_multiplier	1		
n_pulses	1		
acc_power	MV		
tfocus_dist	m		
tfocus_time	s		
tfocus_width	s	Time width of time focusing window	0



"S" - 6

Pulse



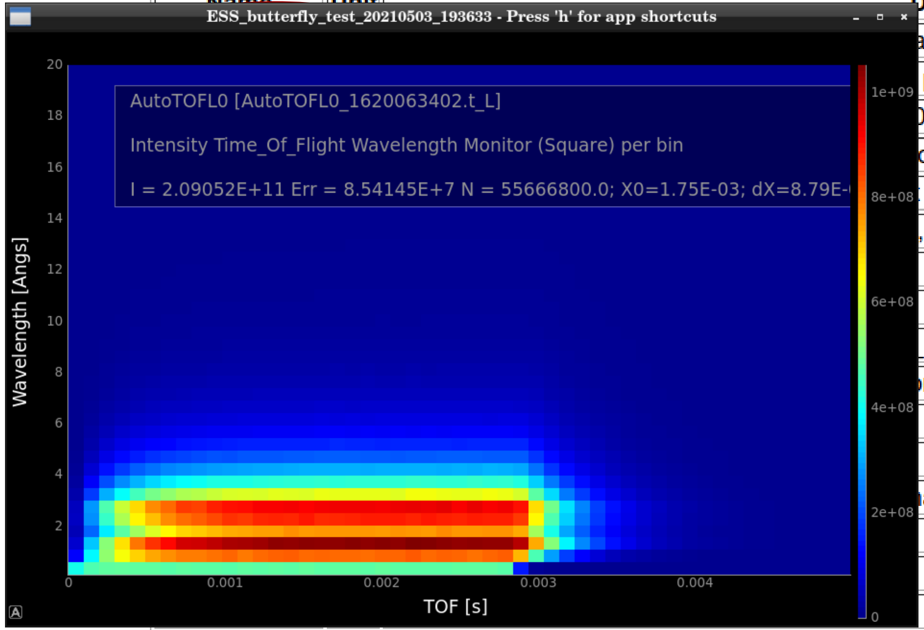
Mozilla Firefox
file:///home/erkn/Sandbox/ESS_buttefly_source/ESS_butterfly_test_20210503_200636/index.html
mcrun ESS_butterfly_test.instr --no-output-files --trace --ncount=300 --dir=ESS_butterfly_test_20210503_200636 sector=S beamline=6
Scatter Markers
Previous
Pause
Next
Ray index 97 / 299
Keep rays
Reset view:
Side
Top
Show BB

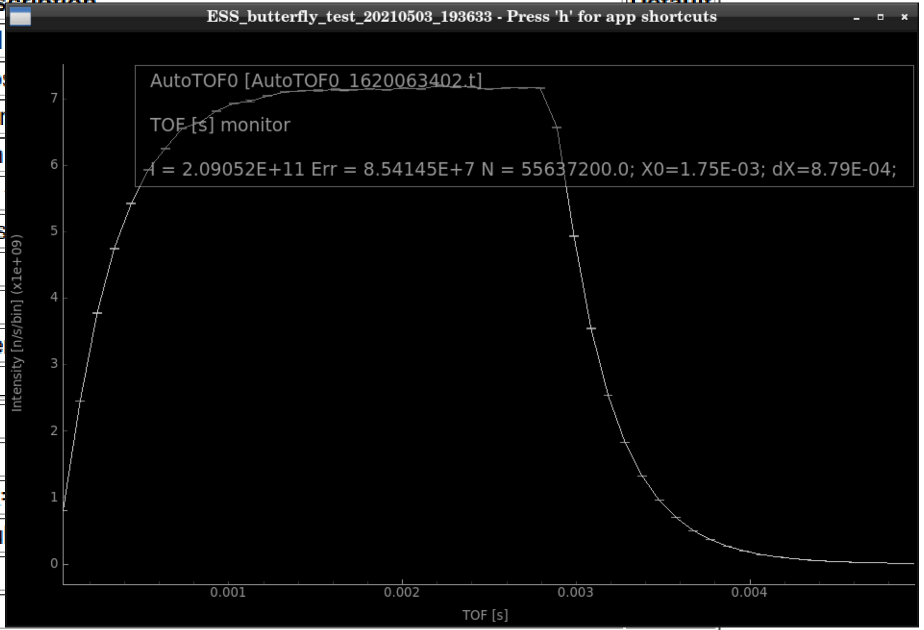
Pulsed Sources: ESS_butterfly

Input parameters

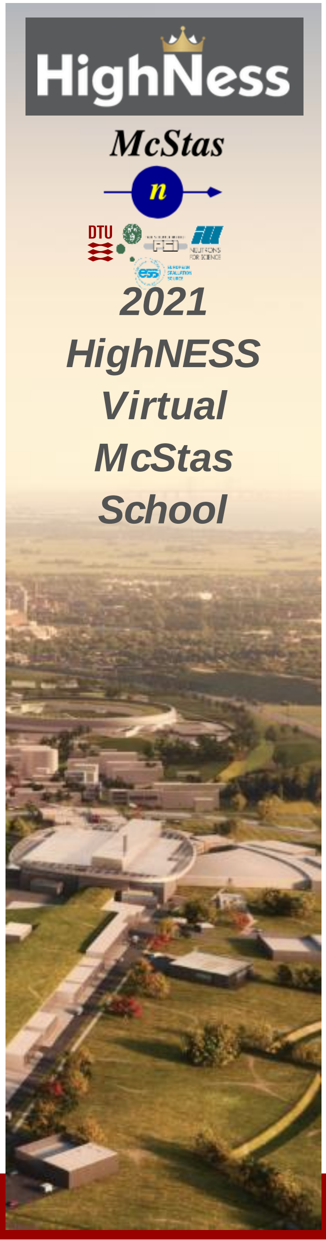
Example: N-1

Parameters in **boldface** are required; the others are optional.





Name	Unit	Description	Default
tfocus_time	s	Time position of time focusing window	0
tfocus_width	s	Time width of time focusing window	0



Pulsed Sources: ESS_butterfly

n_pulses=3

Input parameters

Parameters in **boldface** are required; the others are optional.

Name	Unit	Description	Default
sector	str	Defines the 'sector' of your instrument position. Valid values are "N","S","E" and "W"	"N"
beamline	1	Defines the 'beamline number' of your instrument position. Valid values are 1..10 or 1..11 depending on sector	1
yheight	m	Defines the moderator height. Valid values are 0.03 m and 0.06 m	0.03
cold_frac	1	Defines the statistical fraction of events emitted from the cold part of the moderator	0.5
target_index	1	Relative index of component to focus at, e.g. next is +1 this is used to compute 'dist' automatically.	0
dist	m	Distance from origin to focusing rectangle; at (0,0,dist) - alternatively use target_index	0
focus_xw	m	Width of focusing rectangle	0
focus_yh	m	Height of focusing rectangle	0
c_performance	1	Cold brilliance scalar performance multiplicator c_performance > 0	1
t_performance	1	Thermal brilliance scalar performance multiplicator t_performance > 0	1
Lmin	AA	Minimum wavelength simulated	
Lmax	AA	Maximum wavelength simulated	
tmax_multiplier	1	Defined maximum emission time at moderator, tmax= tmax_multiplier * ESS_PULSE_DURATION.	3
n_pulses	1	Number of pulses simulated. 0 and 1 creates one pulse.	1
acc_power	MW	Accelerator power in MW	5
tfocus_dist	m	Position of time focusing window along z axis	0
tfocus_time	s	Time position of time focusing window	0
tfocus_width	s	Time width of time focusing window	0

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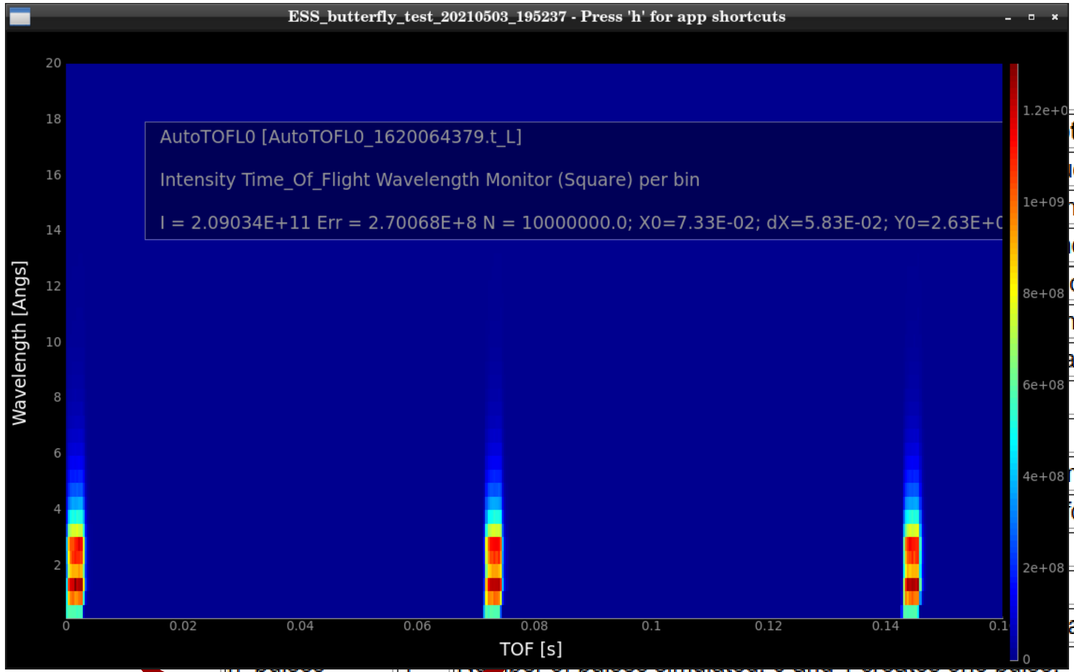
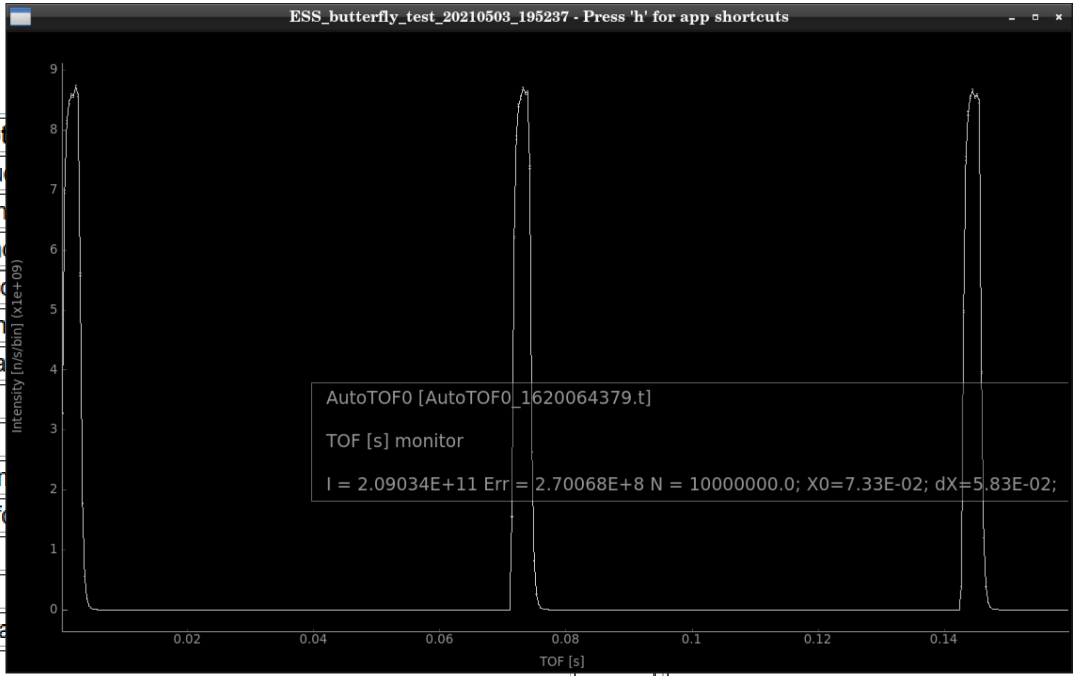
Pulsed Sources: ESS_butterfly

n_pulses=3





n_pulses	1	Number of pulses simulated. 0 and 1 creates one pulse.	1
acc_power	MW	Accelerator power in MW	5
tfocus_dist	m	Position of time focusing window along z axis	0
tfocus_time	s	Time position of time focusing window	0
tfocus_width	s	Time width of time focusing window	0

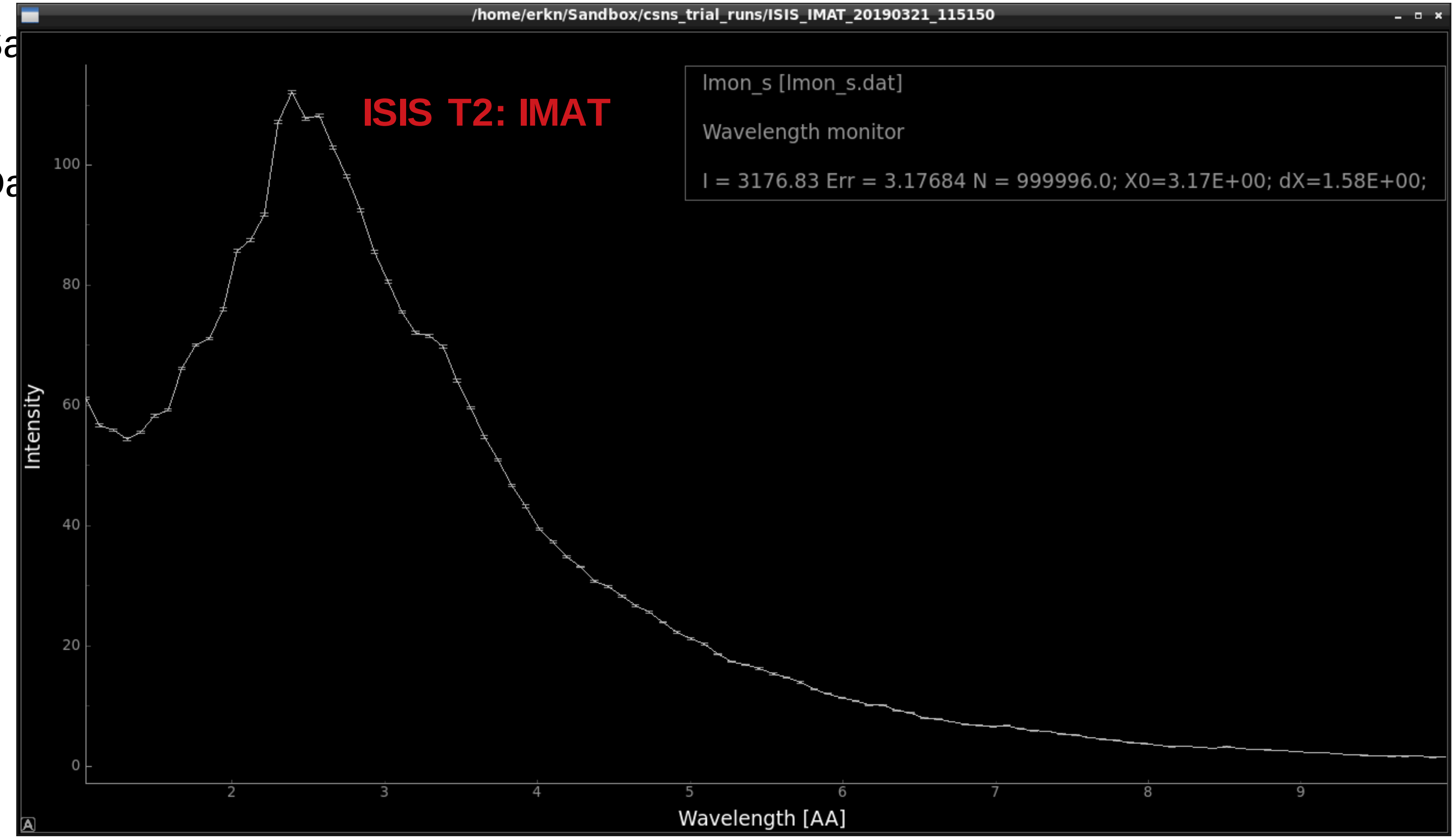
Pulsed Sources: ViewModISIS

- Samples directly from tallies coming from e.g. MCNP target+moderator calculations.

- Data file supplied for each beam port at ISIS.

Pulsed Sources: ViewModISIS

- Sa
- Da



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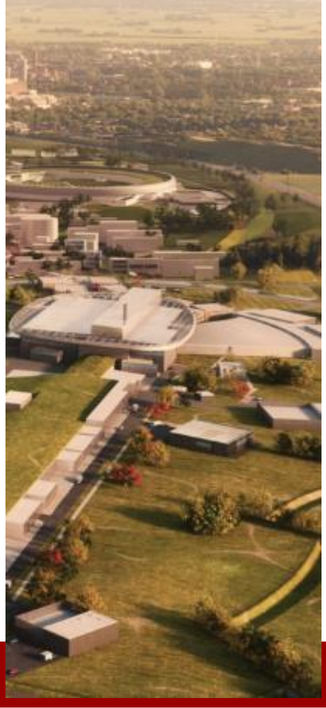

Pulsed Sources: SNS_source

- Samples directly from tallies coming from e.g. MCNP target+moderator calculations.
- Originally from SNS but also used extensively at J-PARC
- Can be used (with the proper input files) to model CSNS, and likely also ISIS.

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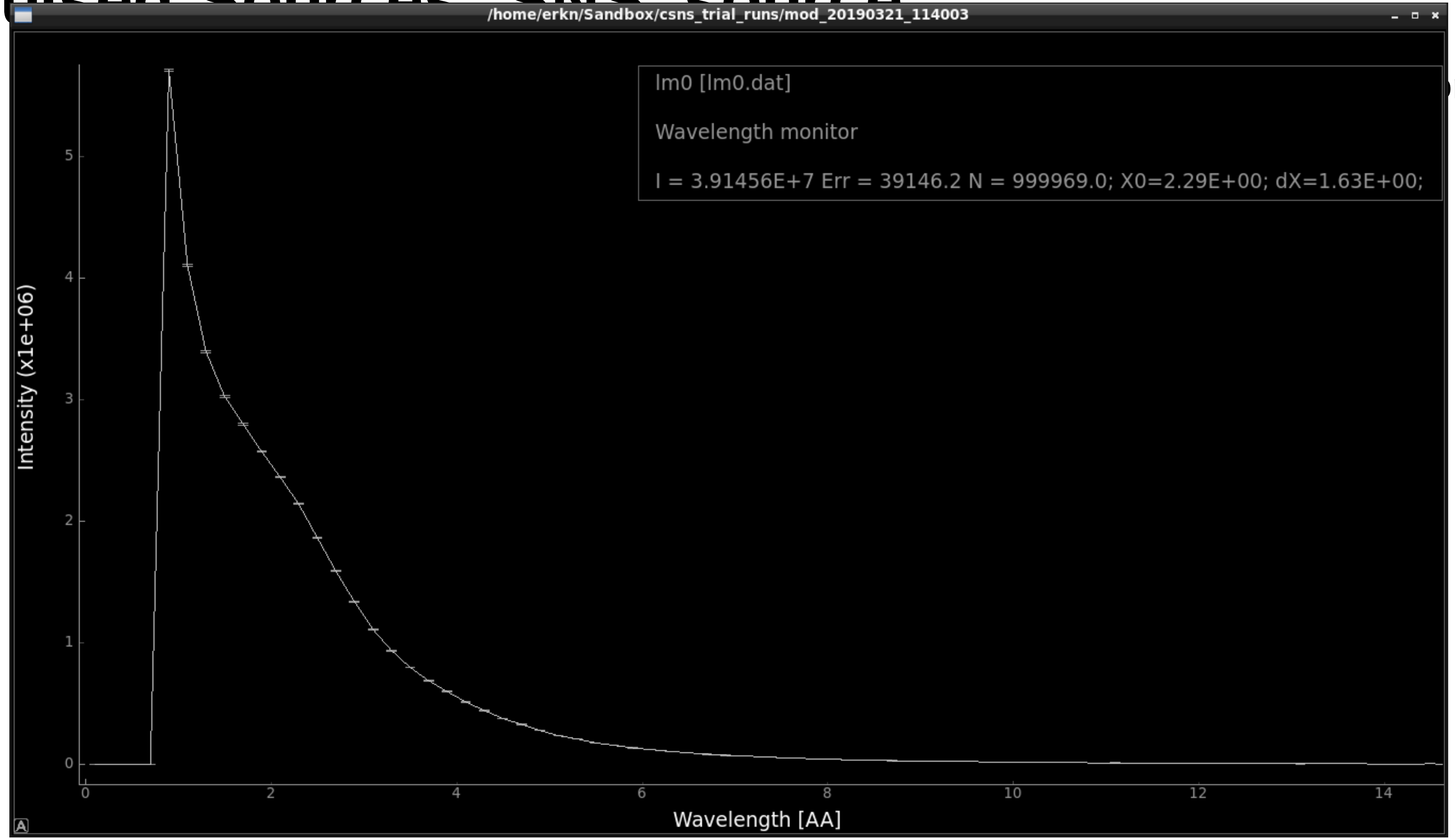
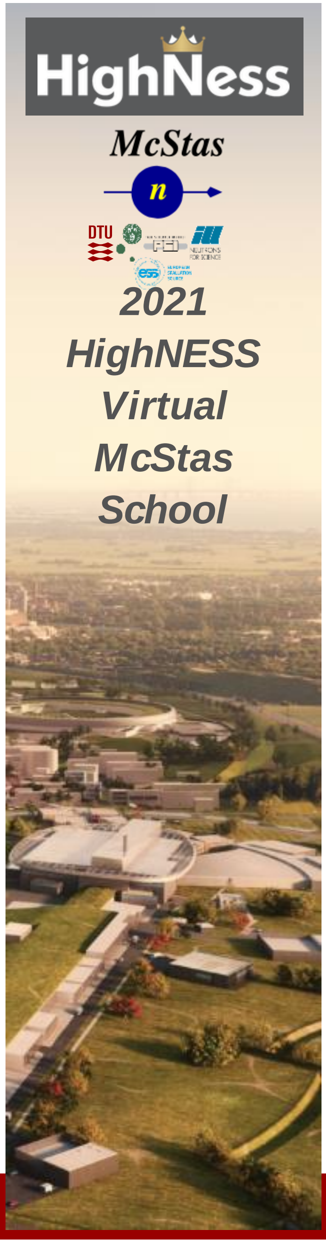
Pulsed Sources: SNS source



ns.



Pulsed Sources: SNS_source_analytic

- Samples from fits of Padé-functions to tallies from SNS_source.
- \- Requires a complex fitting campaign
- \+ Much faster than SNS_source
  \+ “Cleaner” distributions where statistics are sketchy
- Can be used (with the proper input files) to model CSNS-source.

Monitors (some)

1D

- L_monitor → $I(\lambda)$
- TOF_monitor → $I(t)$
- Hdiv_monitor → $I(div_{x})$
- MeanPolLambda → $\langle \bar{P} \rangle(\lambda)$
- E_monitor → $I(E)$

2D

- PSD_monitor → $I(x, y)$
- PSD_monitor_4PI → $I(\theta, \phi)$
- PolLambda_monitor → $I\left(\bar{P}, \lambda\right)$
- Divergence_monitor → $I\left(div_{x}, div_{y}\right)$
- DivPos_monitor → $I(div_{x}, x)$

nD

- Monitor_nD →

$I(X)$

or $I(X, Y)$

or $Z(X, Y, Z)$

or ...

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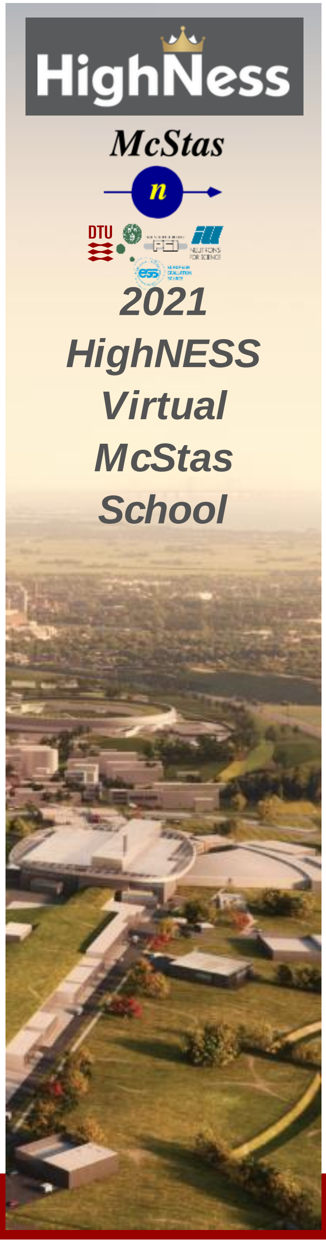
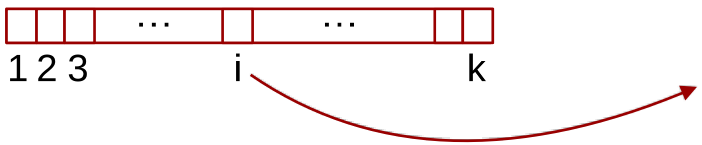
Monitors: Quick examples

```
COMPONENT my_L_monitor = L_monitor(xwidth=0.2, yheight=0.2,
                                   nL=20, filename="Output.L", Lmin=2, Lmax=10)
```



In a histogram sense

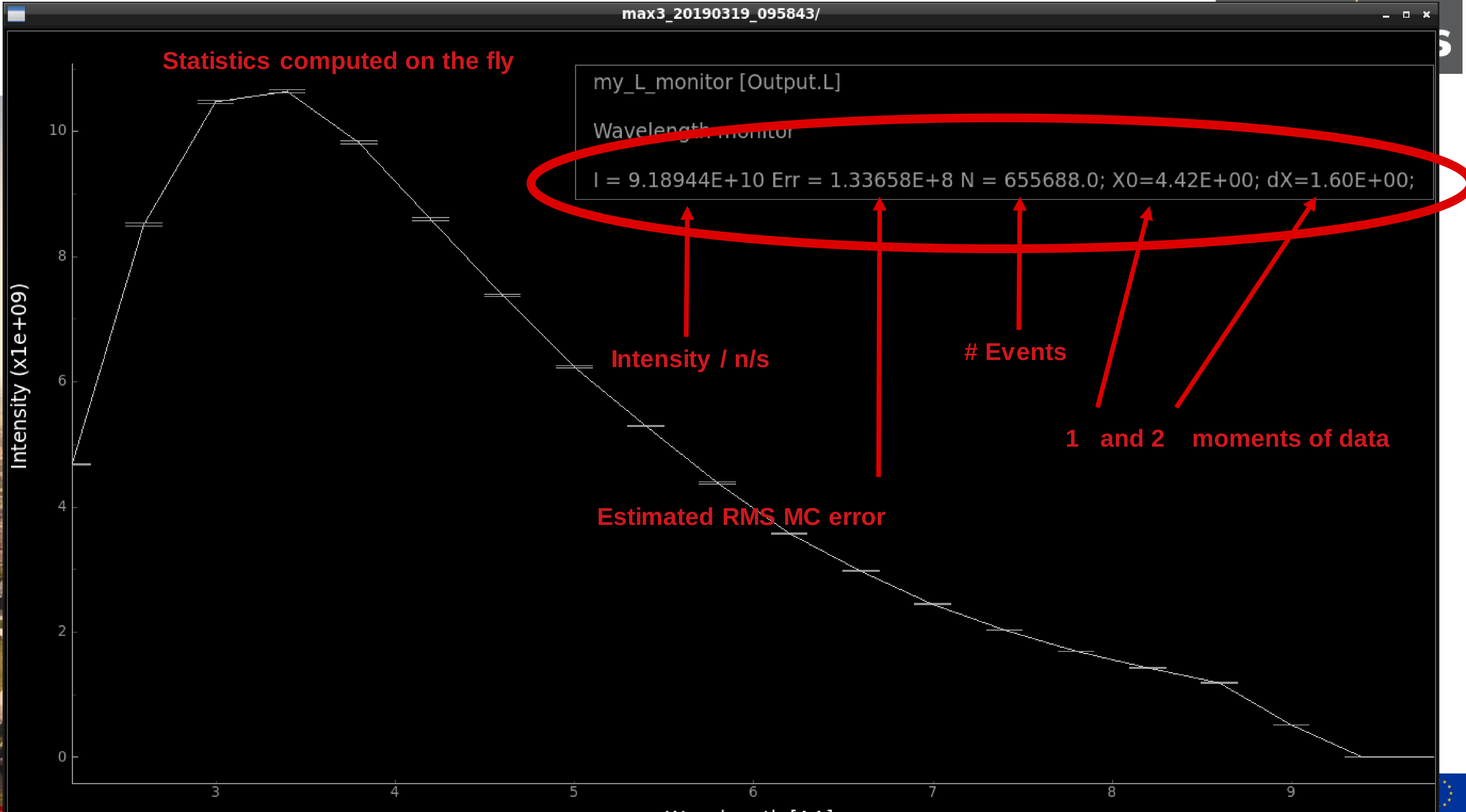
- Imagine a histogram, e.g. **I**(λ)

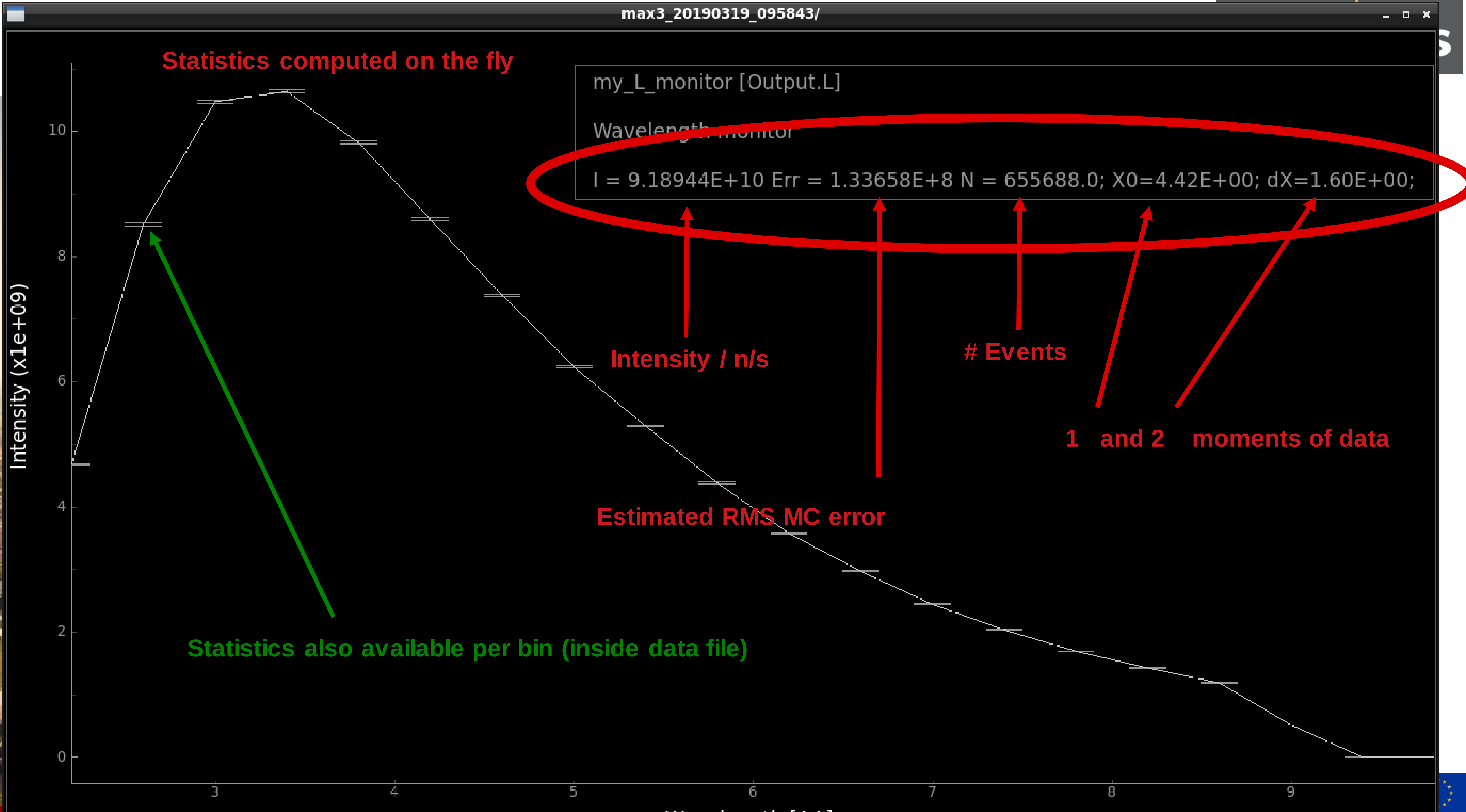


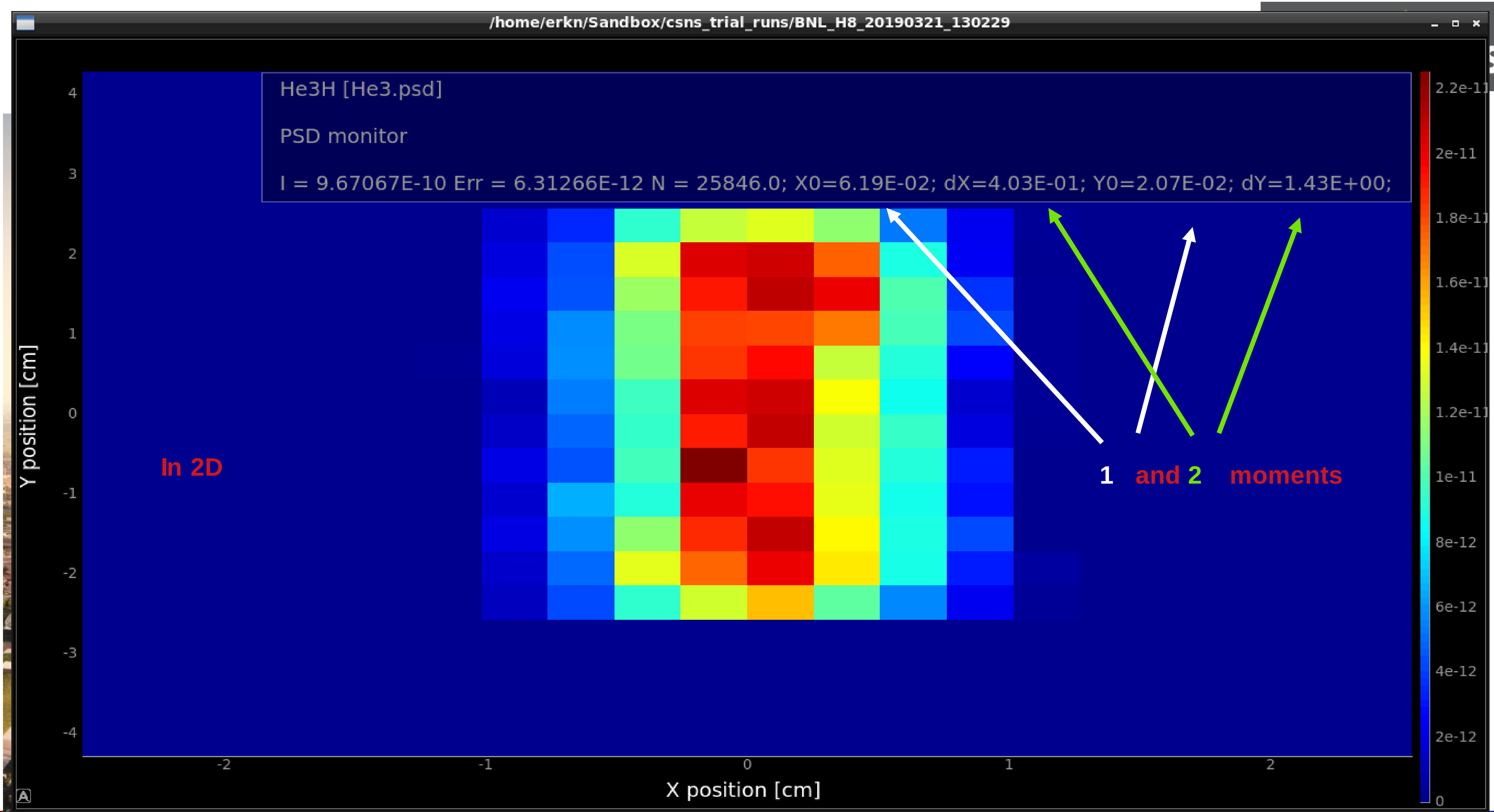
In bin *i*, ***N*** events each carrying a fractional intensity p_j so that

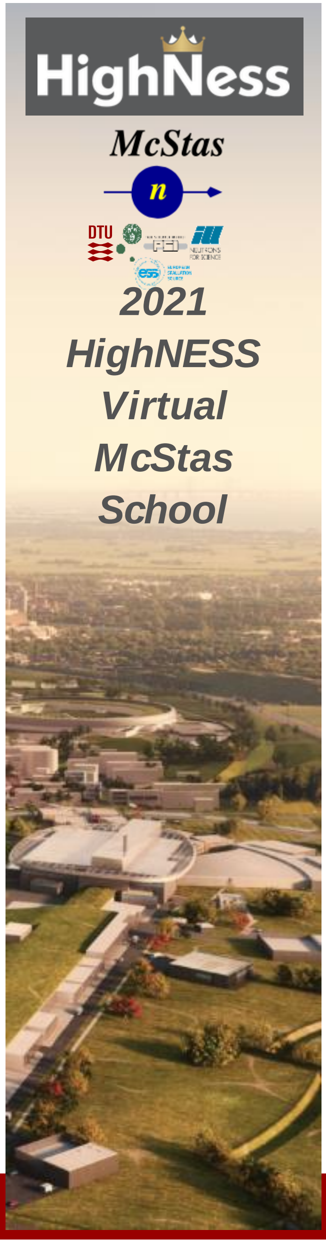
$$I = \sum_N p_j$$

- The RMS variance over that set becomes our statistical error bar ***E***


max3_20190319_095843/
Statistics computed on the fly
my_L_monitor [Output.L]
Wavelength monitor
I = 9.18944E+10 Err = 1.33658E+8 N = 655688.0; X0=4.42E+00; dX=1.60E+00;
Intensity / n/s
Events
1 and 2 moments of data
Estimated RMS MC error
Intensity (x1e+09)
10
8
6
4
2
0
3
4
5
6
7
8
9


max3_20190319_095843/
Statistics computed on the fly
my_L_monitor [Output.L]
I = 9.18944E+10 Err = 1.33658E+8 N = 655688.0; X0=4.42E+00; dX=1.60E+00;
Intensity / n/s
Events
1 and 2 moments of data
Estimated RMS MC error
Statistics also available per bin (inside data file)
Intensity (x1e+09)
10
8
6
4
2
0
3
4
5
6
7
8
9


/home/erkn/Sandbox/csns_trial_runs/BNL_H8_20190321_130229
He3H [He3.psd]
PSD monitor
I = 9.67067E-10 Err = 6.31266E-12 N = 25846.0; X0=6.19E-02; dX=4.03E-01; Y0=2.07E-02; dY=1.43E+00;
In 2D
1 and 2 moments
Y position [cm]
X position [cm]



From "Virtual experiments - the ultimate aim of neutron ray-tracing simulations", K. Lefmann et al., Journal of Neutron Research 16, 97-111 (2008)

Let n be the number of neutron rays reaching the detector, and let the rays have (different) weights, w_i. The simulated intensity is then given by

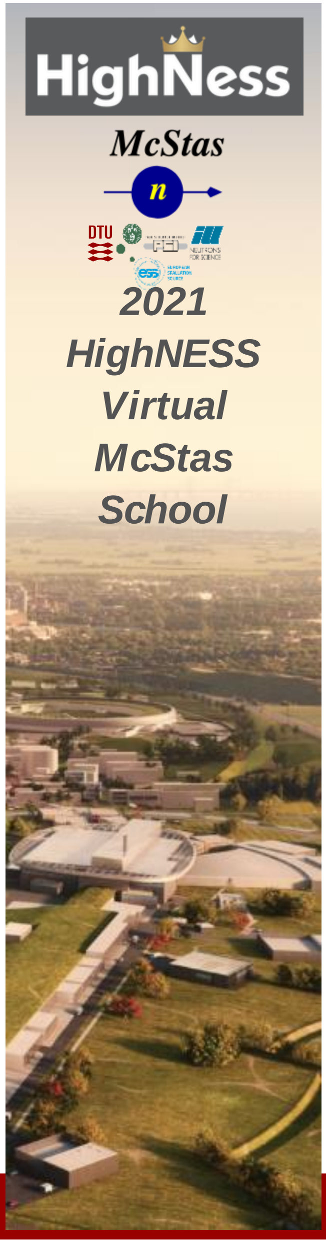
$$I = \sum_{i=1}^{n} w_i. \quad (1)$$

The estimate of the error on this number is calculated in the McStas manual [1], and the standard deviation is approximated by

$$\sigma^2(I) = \sum_{i=1}^{n} w_i^2. \quad (2)$$

In real experiments, $w_i = 1$, whence we reach $I = n$ and $\sigma(I) = \sqrt{I}$ as expected (for counts exceeding 10). Let the virtual time be denoted by t. The simulated counts during this time becomes

$$C = tI, \quad (3)$$



From "Virtual experiments - the ultimate aim of neutron ray-tracing simulations", K. Lefmann et al., Journal of Neutron Research 16, 97-111 (2008)

and its error bar estimate is

$$\sigma^2(C) = t^2\sigma^2(I). \tag{4}$$

However, to simulate a realistic counting statistics, we must fulfill

$$\sigma_{\mathrm{VE}}(C_{\mathrm{VE}}) = \sqrt{C_{\mathrm{VE}}}. \tag{5}$$

This is obtained by adding to (3) a Gaussian noise $E(\Sigma)$ of mean value zero and standard deviation Σ:

$$C_{\mathrm{VE}} = tI + E(\Sigma). \tag{6}$$

The standard deviation for the VE becomes

$$\sigma^2_{\mathrm{VE}}(C) = t^2\sigma^2(I) + \Sigma^2. \tag{7}$$

Now, the requirement (5) allows us to determine Σ:

$$\Sigma^2 = tI - t^2\sigma^2(I). \tag{8}$$

Since Σ^2 must remain positive, we reach an upper limit on t

$$t_{\max} = \frac{I}{\sigma^2(I)}. \tag{9}$$

Sketch of an algorithm…

1. On a given McStas histogram

2. For the non-zero bins, calculate

$$t_{\max} = \frac{I}{\sigma^2(I)}.$$

The *smallest* $t_{\mathtt{max}}$ defines the "maximal counting time" allowed by your statistics

3. Preferably a "background" should be added - use a "known experimental value" or an estimate…

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Monitor_nD

A general monitor for 0D/1D/2D records

The all-in-one , swiss-army-knife of monitors

***Monitor_nD** can have almost any shape, and record any requested standard quantities*

Monitor_nD

A general monitor for 0D/1D/2D records

Examples

```
COMPONENT MyMon = Monitor_nD( xwidth = 0.1, yheight = 0.1, zdepth = 0,
                  options = "intensity per cm2 angle,limits=[-5 5],
                  bins=10,with borders, file = mon1")

            options = "banana, theta limits=[10,130], bins=120, y"

            options = "multiple kx ky kz, auto abs log t, and list all neutrons"
```

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Monitor_nD

… or monitor just about anything:

```
COMPONENT MyMon = Monitor_nD(xwidth = 0.1, yheight = 0.1,
    user1=age, username1="Age of the Captain [years]",
    options="user1, auto")
```

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Exercise 2:

Head over to the github site and continue the exercise we started before:

https://github.com/McStasMcXtrace/Schools/tree/master/ESS_May_2021/Wednesday_May_5th/2_Component_basics/Exercise

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