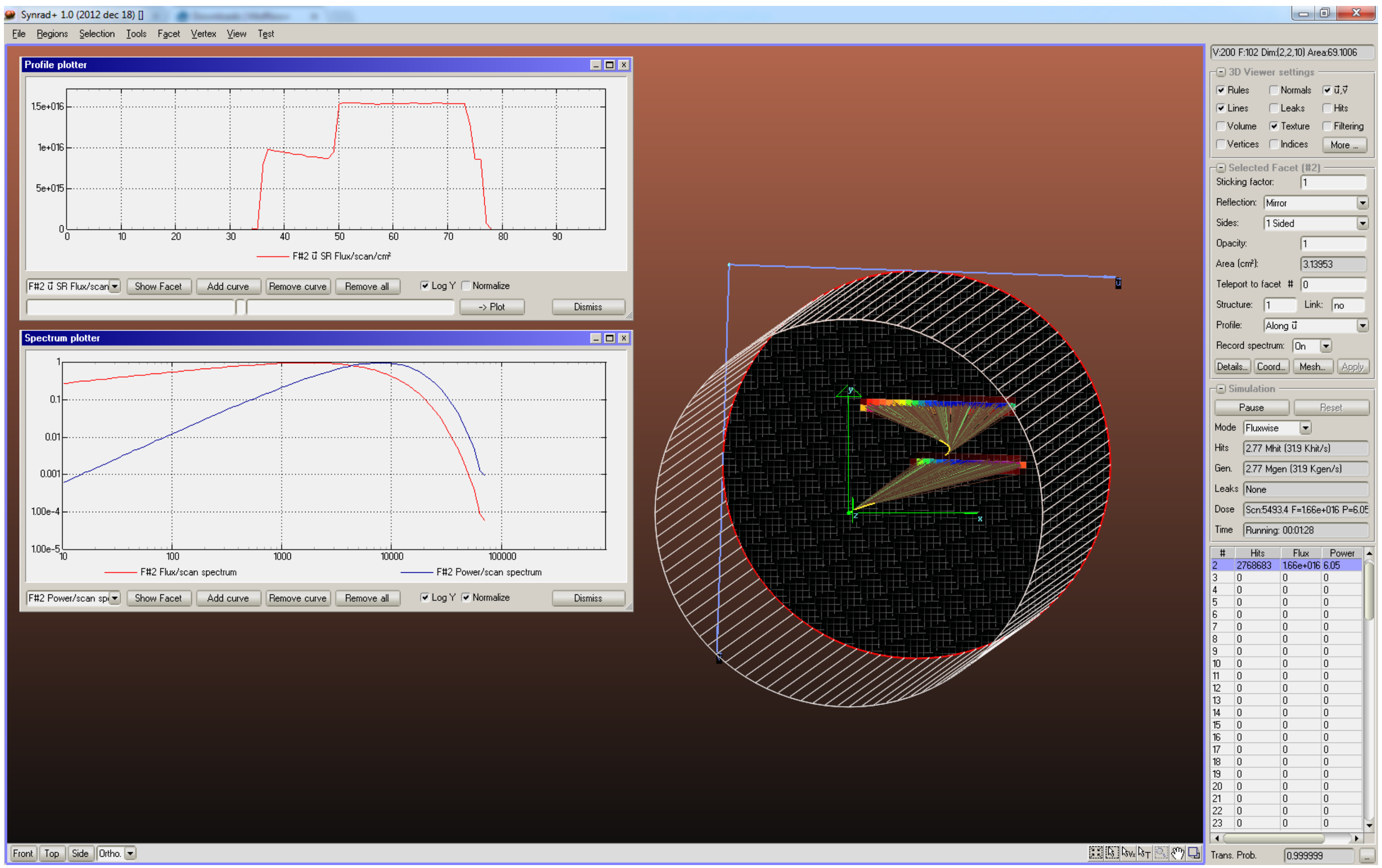
A 10-minute introduction to

# SynRad+

A test-particle Monte Carlo simulator for synchrotron radiation

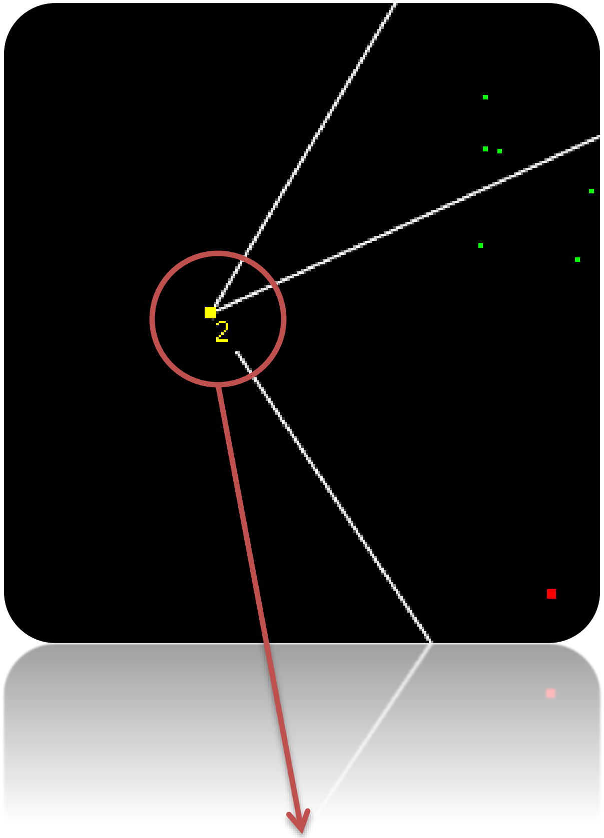


# The basics

First, let's learn the SynRad+ terminology and the interface in a few slides.

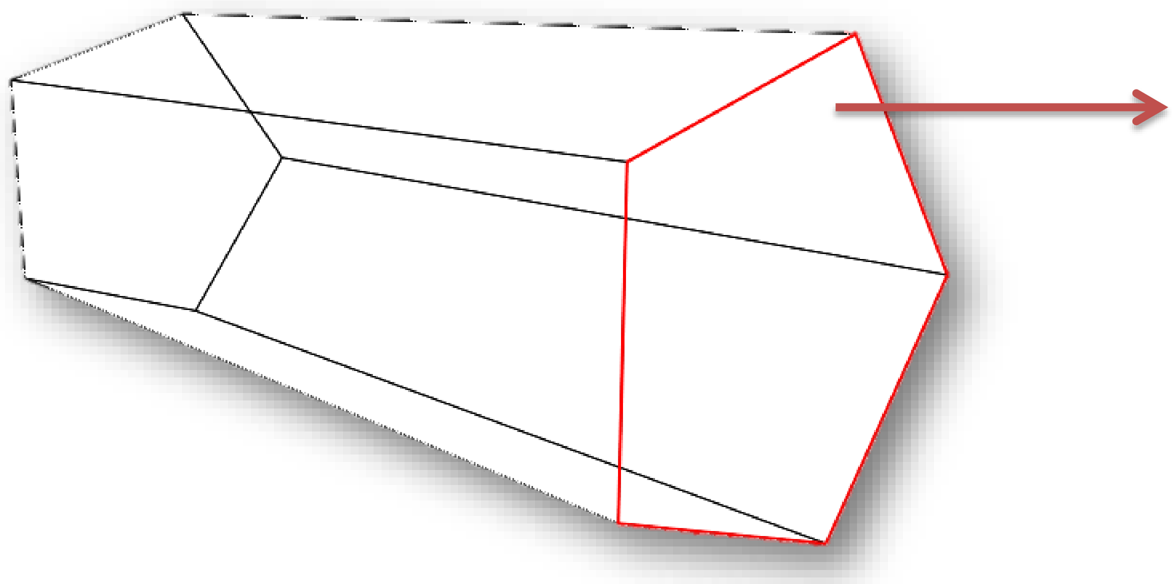
Or, if you prefer learning by doing it, skip to the tutorial part.

# Vertex




A vertex is a point in the 3D space.

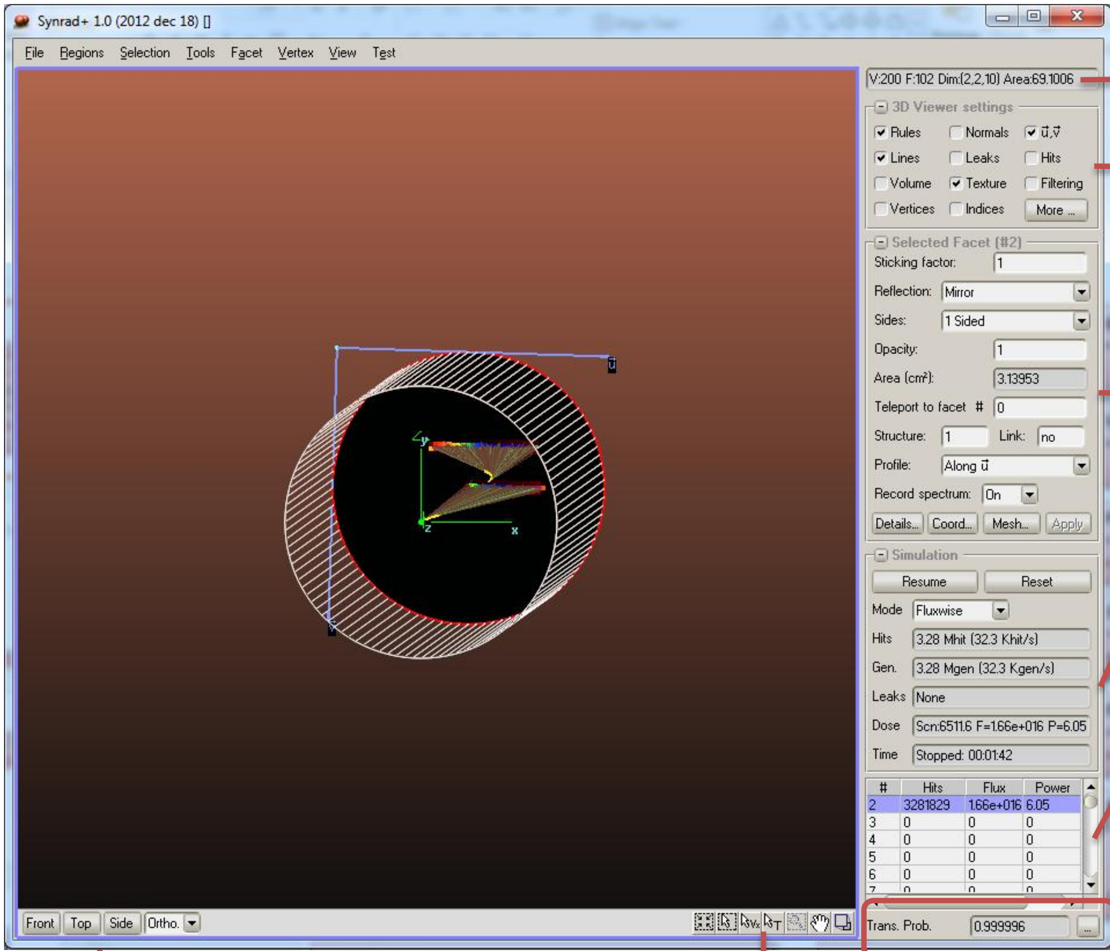
# Facet



A facet, also called polygon is a side of our 3D object. It is an outline that connects vertices.

It is an important term in SynRad+, as many properties (material, reflection type, counting modes) are *facet parameters,* which means that they can be adjusted individually for each facet.

# The interface




**Geometry properties**
- Shows information about the geometry size, number of vertices and facets

**View settings**
- Change view settings for the current *viewer* (see next slide)

**Facet parameters**
- Change facet properties
- Access further features (mesh, coordinates,…)

**Simulation control**
- Start/stop/reset simulation
- View simulation statistics

**Facet list**
- See the number of MC hits and absorbed flux on each facet
- Select facets (multiple: hold CTRL)

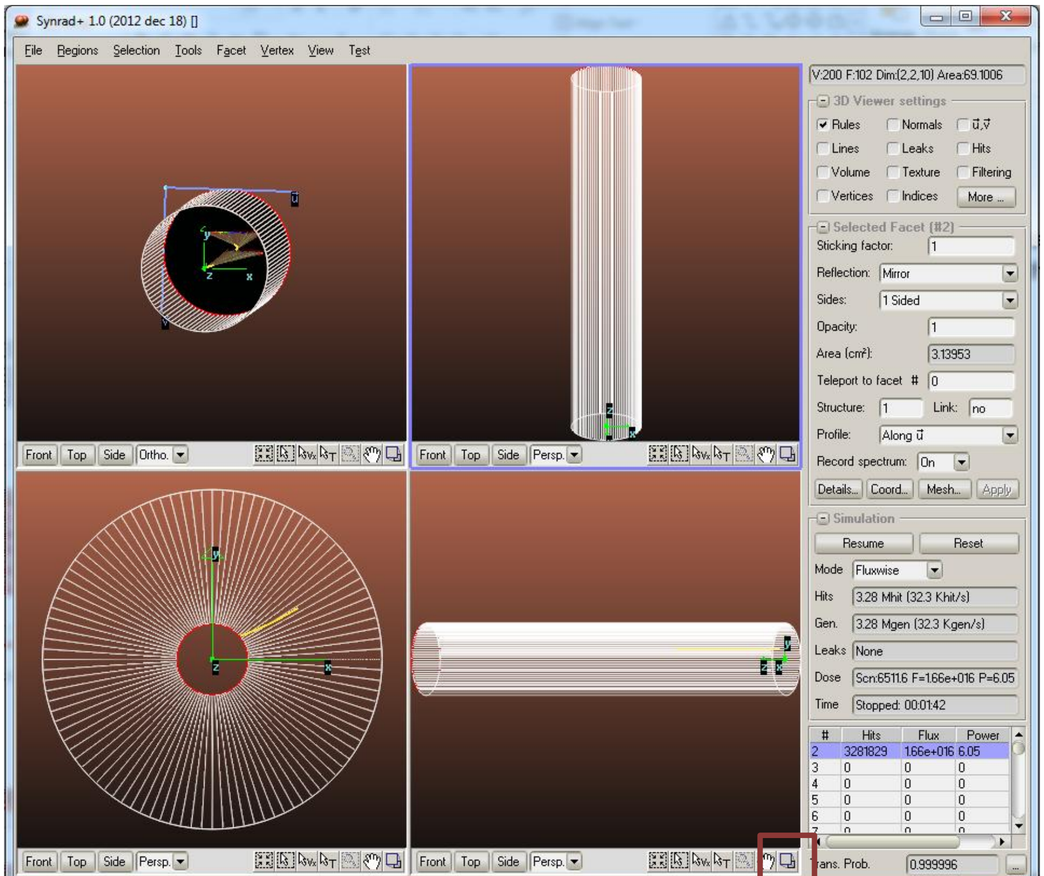
**Formulas**
- A list of formulas that get calculated as the simulation runs
- Use Edit / Formulas menu to add / remove

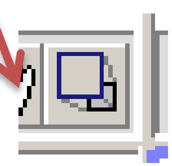
**View Selector**
- Set camera to preset positions
- Change projection type (orthographic / perspective)

**Tool Selector**
- Changes the mouse pointer’s function
- Will be explained later in this guide

# The viewers

SynRad allows you to use four different *viewers*, each of them can have different view settings and different camera angles. The active viewer is marked by the thick violet outline



**Expand button**
Use this to maximize the current viewer

# Camera control

**Left click**
To select a facet, a vertex or a trajectory point, depending on the tool used (next slide)

*Holding ALT and dragging with the left mouse button also moves the camera*

**Press and hold**
the mousewheel to drag the camera

**Scroll**
The mousewheel to zoom in/out

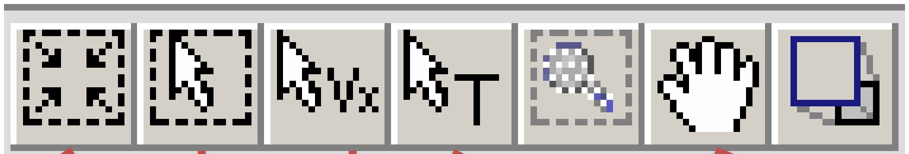
*Holding CTRL scrolls slower, holding SHIFT scrolls faster*

**Hold and drag**
the right mouse button to rotate the camera

*Holding CTRL and dragging with the right button also zooms in/out*

# Viewer Tools

To select things



**Autoscale**
Click to fit the whole geometry on in the viewer

**Facet selector**
Default setting. If you click several times on the screen, facets under your mouse pointer get selected in a cycle.

You can also **draw a selection box** by holding the left button to select facets inside the box.

**CTRL-click:** subtract from selection
**SHIFT-click:** add to selection

**Vertex selector**
Click near a vertex on the screen: the vertex closest to your pointer gets selected.

You can also **draw a selection box** by holding the left button to select vertices inside the box.

**CTRL-click:** subtract from selection
**SHIFT-click:** add to selection

**Trajectory info**
Allows you to read and visualize the direction, curvature and magnetic field vectors of a given trajectory point.

Click on a part of the trajectory and the nearest calculated point will be selected

**Hand tool**
Now deprecated by middle mouse button drag.

If selected, you can move the camera by dragging with the left mouse button.

# Facet parameters

These are parameters can be set facet-by-facet:

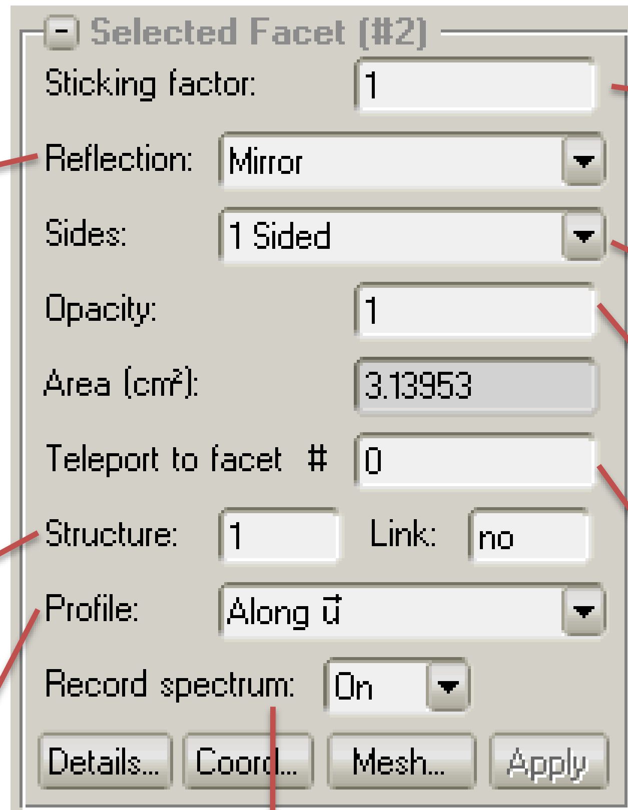
**Reflection type**
*Mirror*: photons get reflected by their incident angle

*Diffuse*: Photons get reflected with a cosine-distributes angle (Lambertian surface)

*Material*: Photons get reflected taking their energy, incident angle and material roughness into account

**Structures**
Structures are parts of the geometry that are calculated separately. They allow some speedup of the simulation, but they are not part of this tutorial

**Profile**
If enabled, the absorbed flux and power distribution will be calculated along the local U or V vectors. Useful if you want to plot a curve within Synrad




**Sticking factor**
Probability that a photon hitting the facet will be absorbed

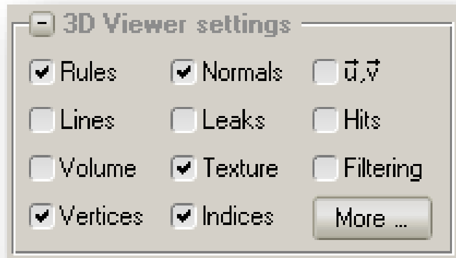
**One- or two-sidedness**
A one-sided facet is opaque on the side where its normal vector is pointing, whereas a two-sided will catch photons from both sides.

**Opacity**
Probability that a photon going through the facet will interact with it

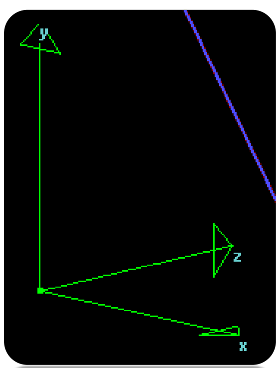
**Teleport destination**
Particles hitting this facet will get transferred to the entered facet index (for periodic structures)

**Record spectrum**
Calculate energy spectrum of incident photons on the facet

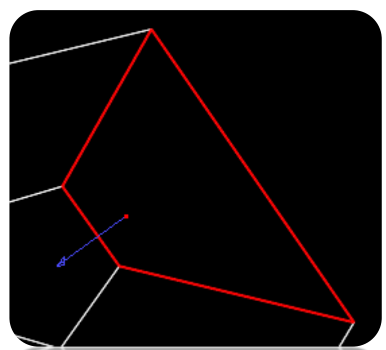
# Viewer parameters



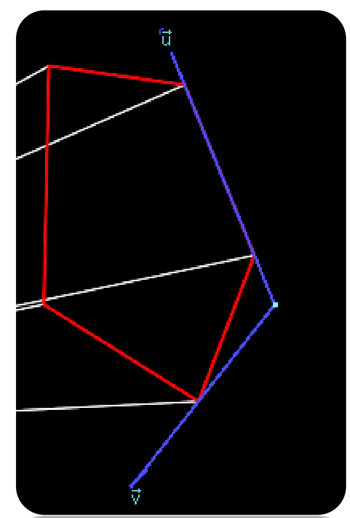

**Rules**
Toggle the base vectors of the coordinate system



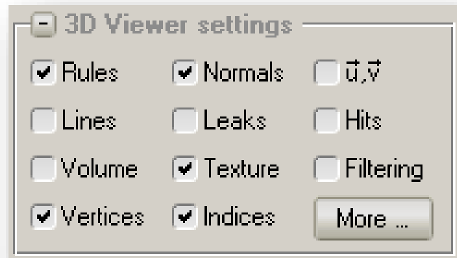

**Normals**
Show the orientation of the facet (interesting in case of 1-sided facets)



**U, V vectors**
The own 2D coordinate system of the selected facet



# Viewer parameters




**Lines**

Photon trajectories

Transparent lines carry less power, opaques carry more (if generated fluxwise)

**Leaks**

If a photon escapes from the system, show where the last hit occurred and in what direction the photon went before leaving

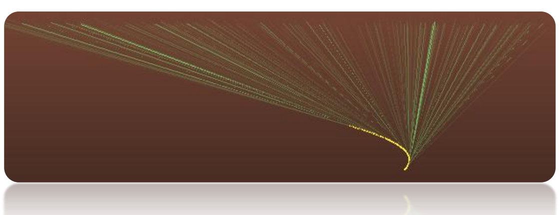
**Hits**

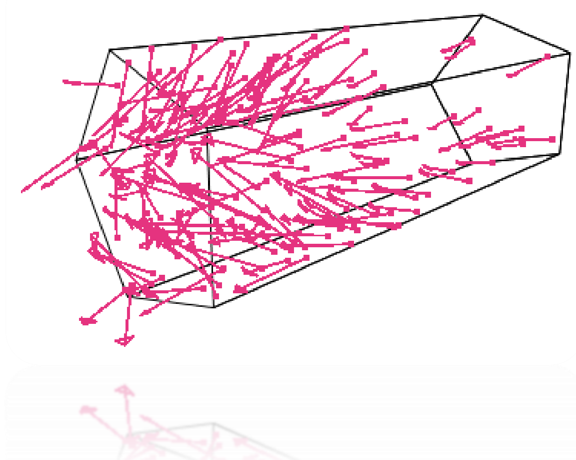
Photon collisions with facets.

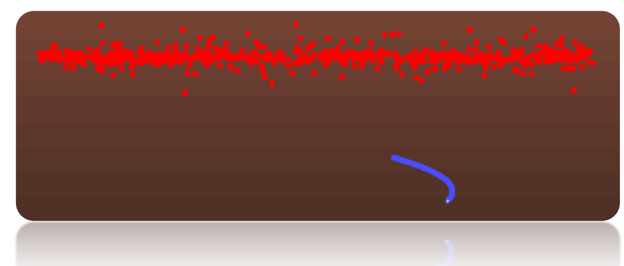
**Red**: Absorption

**Blue**: Photon creation

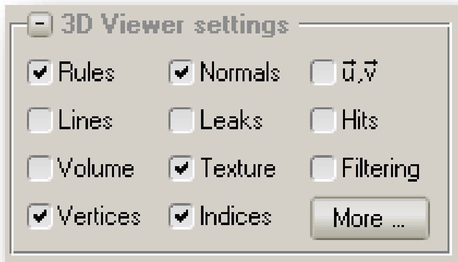
**Green**: Reflection





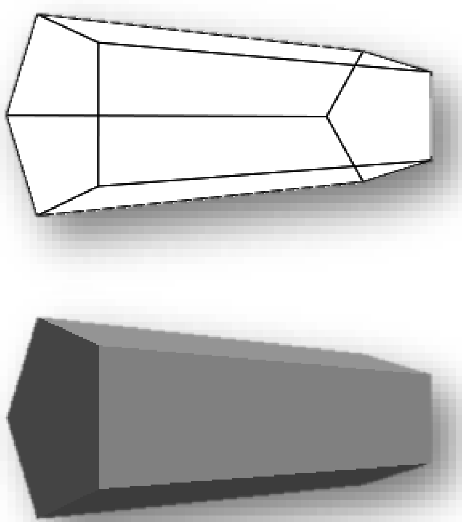


# Viewer parameters



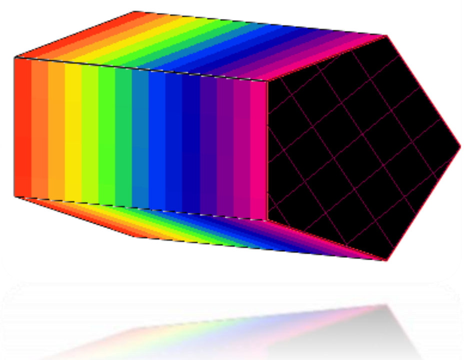

**Volume**

Switch between volumetric or wireframe view mode



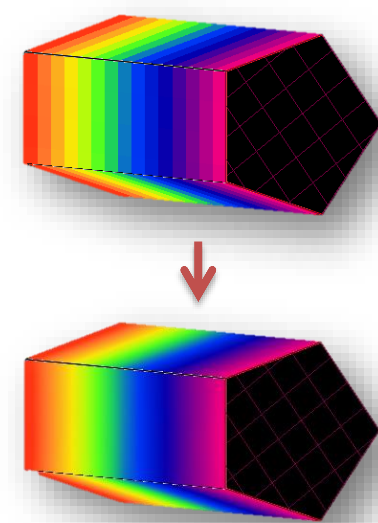
**Texture**

Show or hide textures (see later)

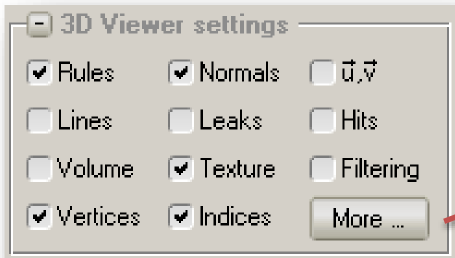


**Filtering**

Apply a Gauss filter (smoothing) to textures

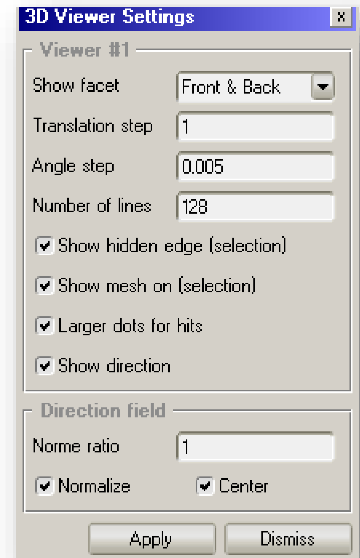


# Viewer parameters





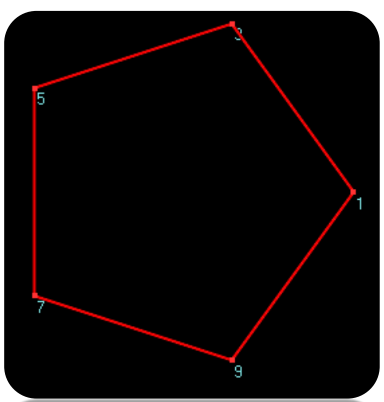
Further options…




Not part of this quick start guide.

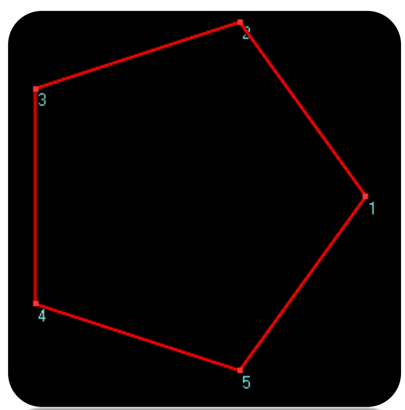
**Vertices**

Shows the identifier of vertices on selected facets



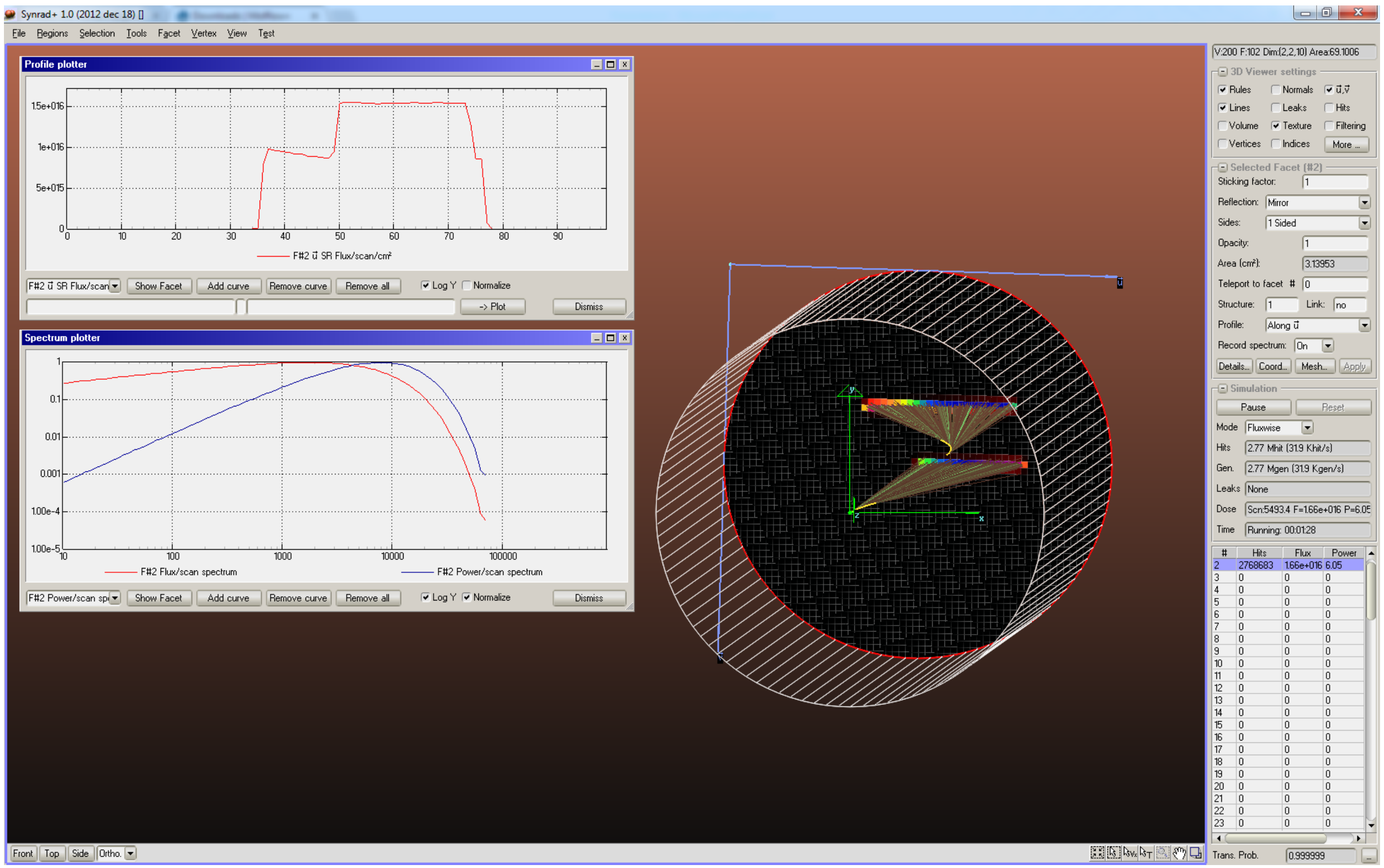

**Indices**

Shows the index of vertices on a given facets (starting from 1 for each facet)



# Tutorial: two dipoles in a tube

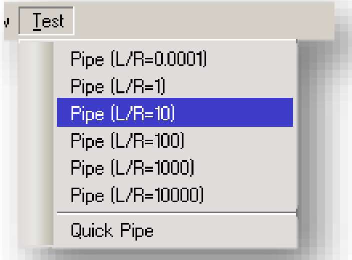
In this example, we insert two dipoles in a simple tube, and visualize the flux and power distribution of the synchrotron radiation of a beam. We also calculate the power spectrum.




All steps of this tutorial are demonstrated in a video on the website.

# Create geometry

- From the Test menu, choose a test pipe with L/R ratio of 10

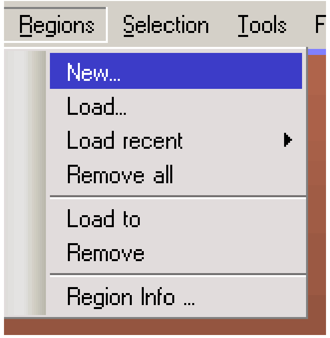



- Let its surface consist of 20 facets:

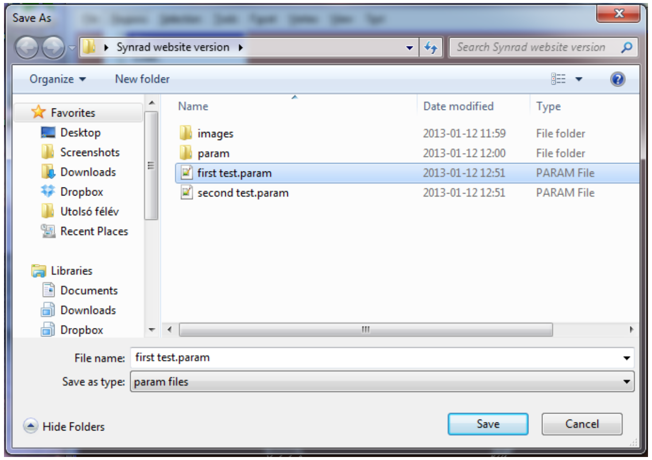

- Now we have a (simple) geometry. It's time to add some magnetic regions where the beam will be calculated.

# Add a region

- Time to add our first magnetic region! Click on Regions / New…

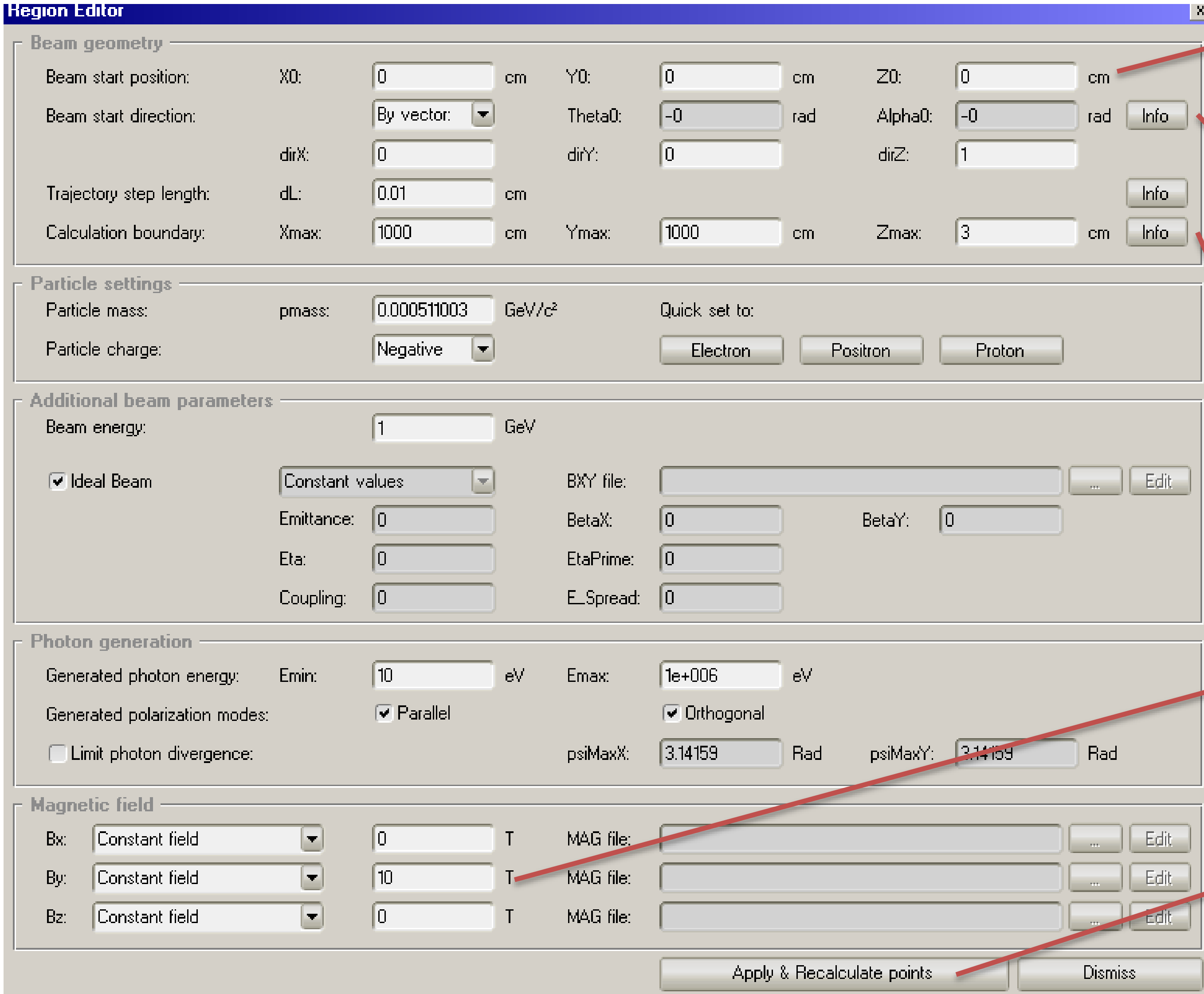



- For compatibility reasons, regions are not part of the geometry file, they are saved separately. Specify the location where the new region will be saved:



# Add a region

- Now we will set up a beam passing a simple dipole:




**Start position**
The beam will start from the origin (0,0,0)

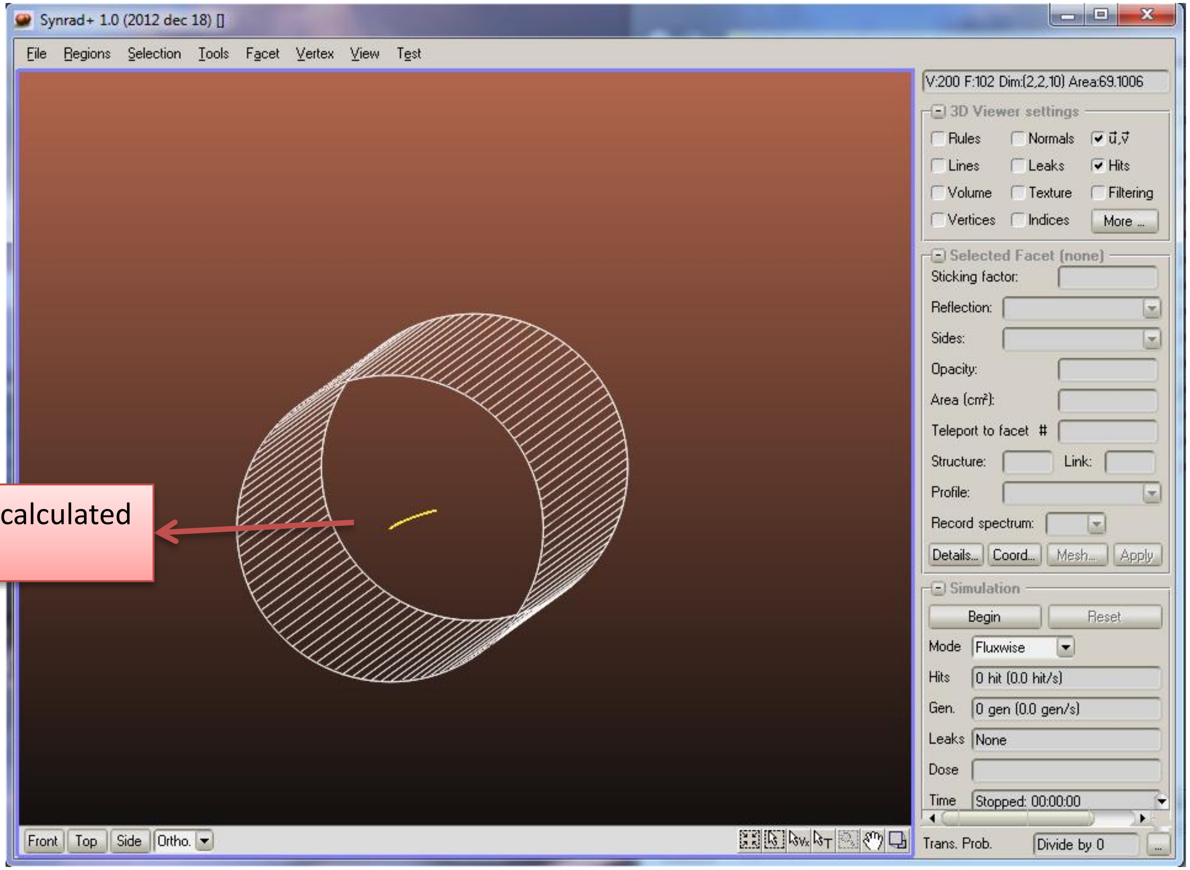
**Start direction**
It will start in the Z direction (0,0,1). Click the INFO button to see conversion between angles and direction vector

**Calculation boundary**
The trajectory of the beam will be calculated until one of its coordinates reaches these limits. Set the Z limit to 3cm: the beam will go from Z=0 to Z=3

**Magnetic field**
Set up a simple dipole: the Y component of the B vector is 10 Tesla

**Calculate trajectory**
Click on the Apply button

# Second region



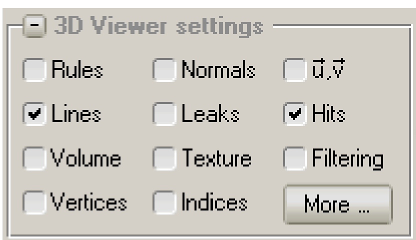

The trajectory we just calculated is shown in yellow

*Optional:*
Repeat the above steps to **add a second region.** Change the starting point to 0.5,0.5,0, the Z limit to 3.0, and optionally make small changes in the magnetic field.

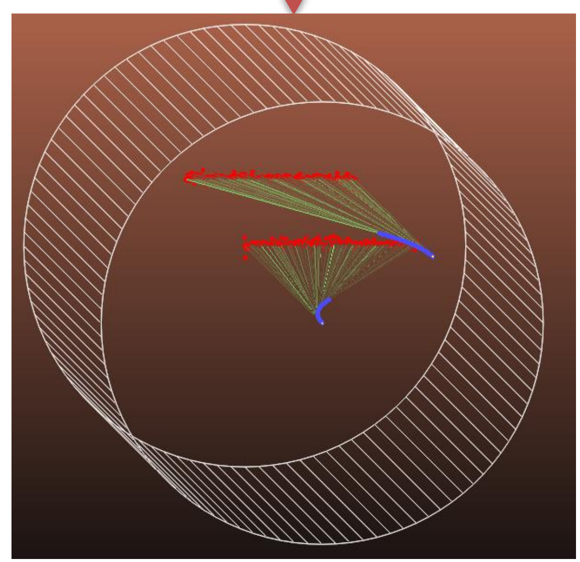
# Begin the simulation

- Now our simple system is ready. Launch the simulation by clicking

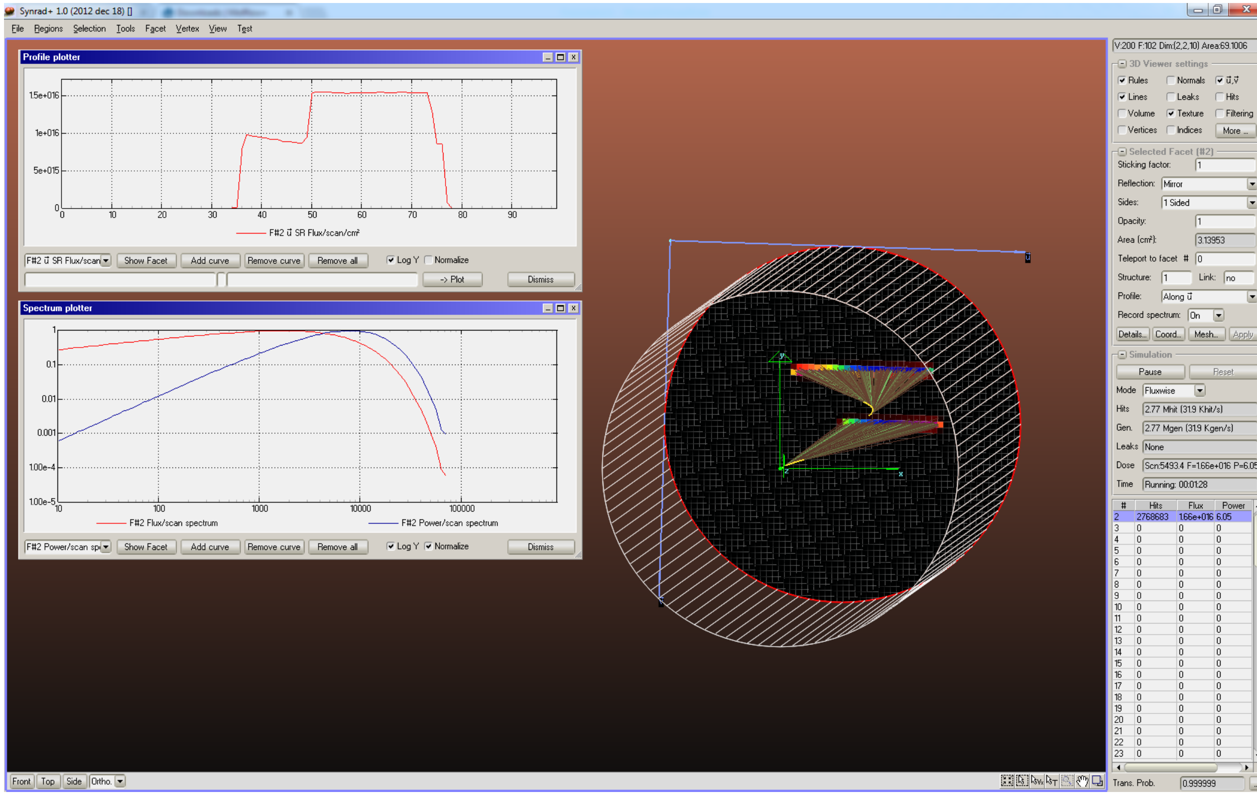

- Visualize what's happening by turning on hits and lines display:




Turning on lines and hits display shows you the path of the photons



# Doing calculations




As your first result, absorbed flux and power is shown for each facet in the bottom right list.

Our system does the physics already, however, we'd like to obtain results. In the following, we'll see how to add *textures*, which are color-coded surfaces that show the distribution of SR flux and SR power.

We'll also set up *profiles,* distribution of the above along a line.

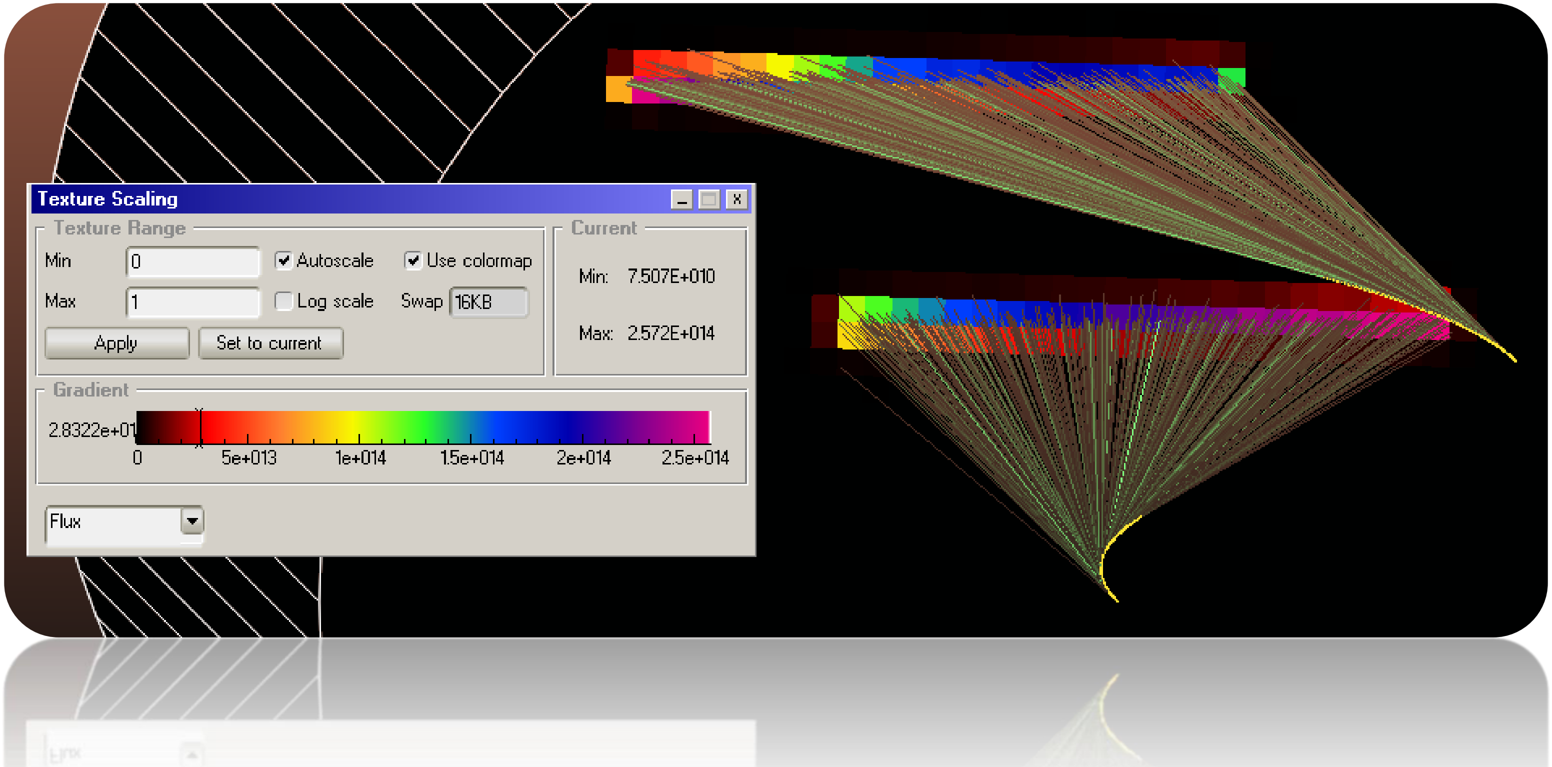
Finally, we'll calculate the *spectrum,* the energy distribution of the incident photons.

**Normalization**

Results are normalized *per scan.* One scan is when the number of generated photons equal the umber of calculated trajectory points (statistically one photon is emitted from each point).

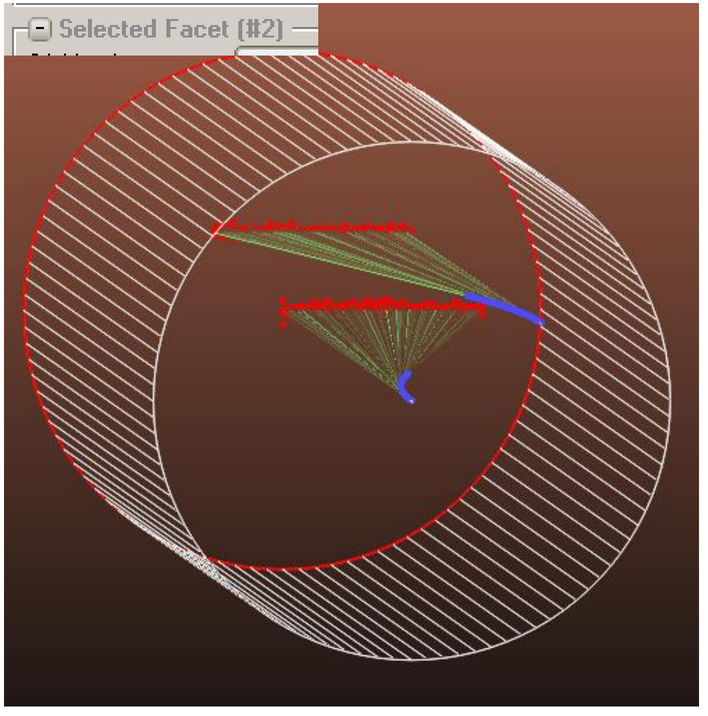
# Adding a Texture

- Textures divide facet surface into *cells,* and each cell counts the SR flux and SR power incident on them



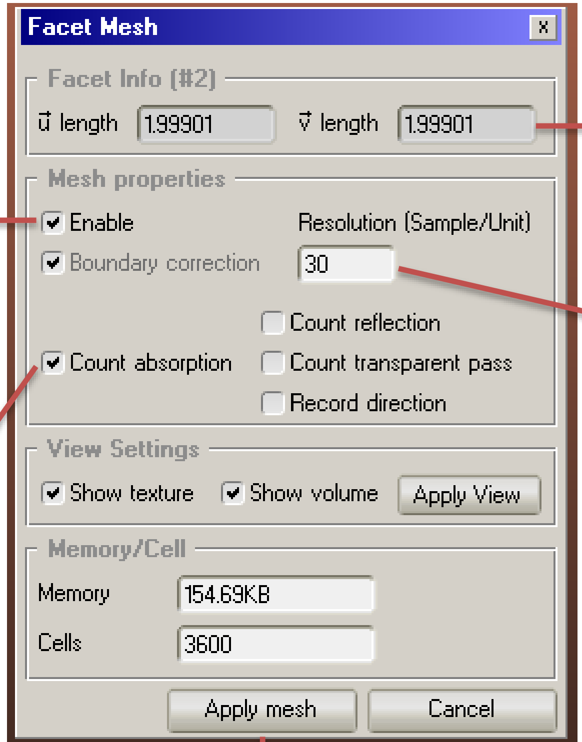
# Adding a Texture

- Select a few (or all) facets where you'd like to visualize and calculate incident flux and power. Select multiple facets by holding the SHIFT key, unselect by holding the CTRL key:



# Adding a Texture

- Add a MESH. A mesh splits the facet into little square blocks where the flux and power are individually calculated. Click Mesh... in Facet parameters:




**1. Facet dimensions**
Shows the bounding box size of the facet. It's 2cm*2cm for the R=1 circle.

**2. Check ENABLE**
So a mesh will be added

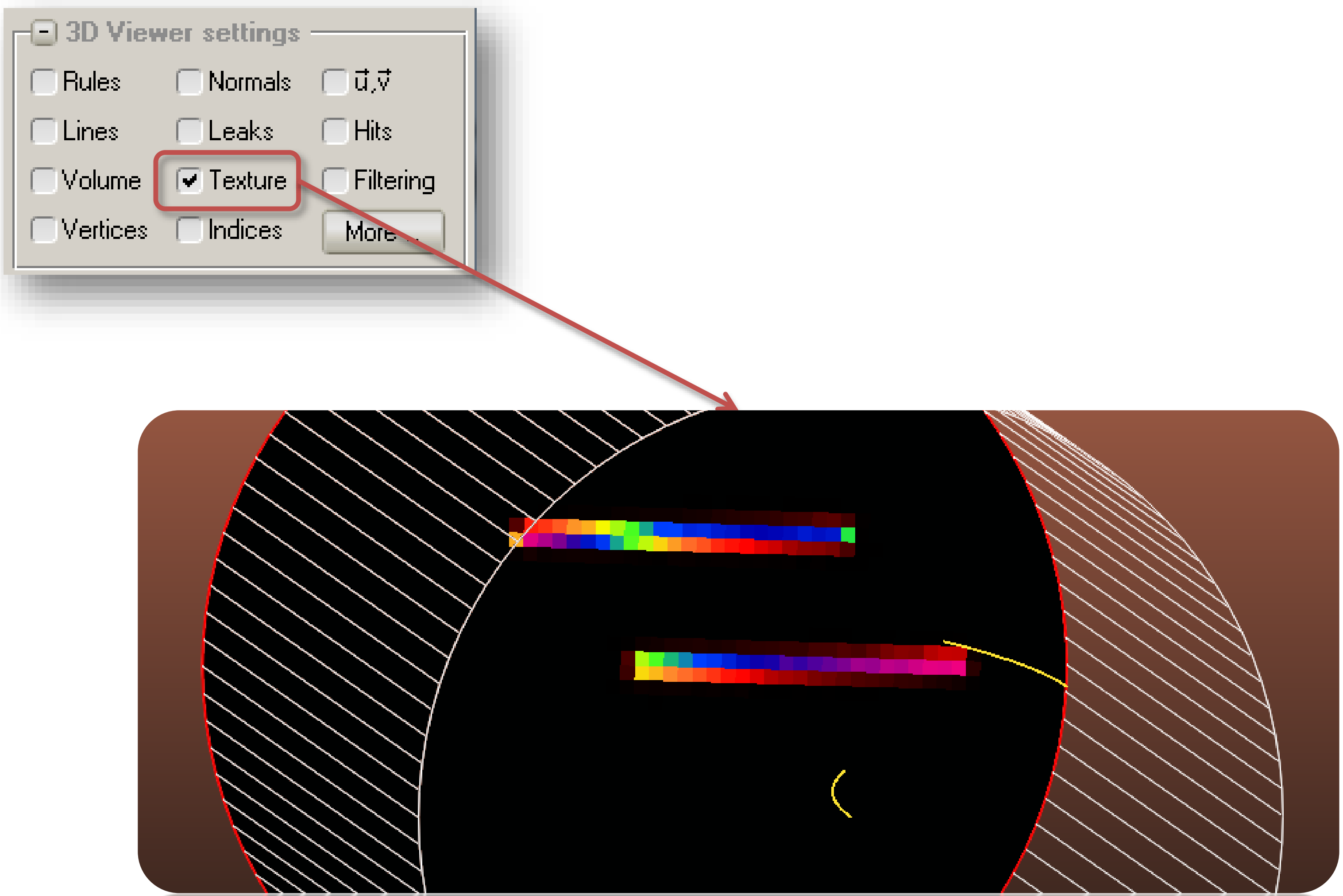
**3. Set resolution**
We'll use 30 samples / cm. So one cell will be 0.033*0.033cm.

**4. Define what to count**
In this example, we want to visualize the incident flux and power, so we check **absorption.**

**5. Apply mesh**

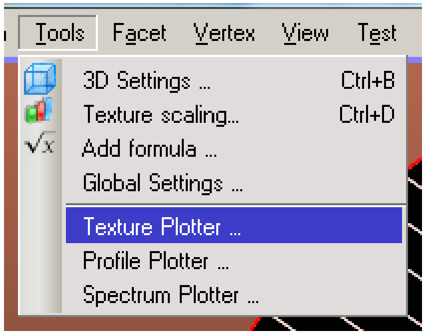
# Adding a Texture

- Turn on “Texture” in the viewer parameters to see the texture:

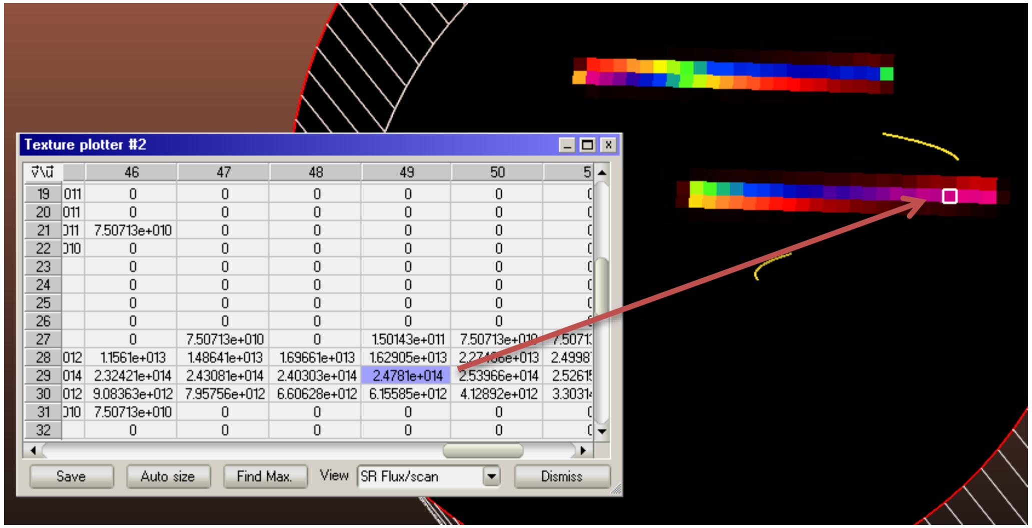


# Adding a Texture

View texture block values by selecting a facet with mesh and opening the Texture Plotter:




Selected cells' position will be outlined on the facet:

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| 28 | 012 | 1.1561e+013 | 1.48641e+013 | 1.69661e+013 | 1.62905e+013 | 2.27[illegible]e+013 | 2.4998 |
| 29 | 014 | 2.32421e+014 | 2.43081e+014 | 2.40303e+014 | 2.4781e+014 | 2.53966e+014 | 2.5261 |
| 30 | 012 | 9.08363e+012 | 7.95756e+012 | 6.60628e+012 | 6.15585e+012 | 4.12892e+012 | 3.3031 |
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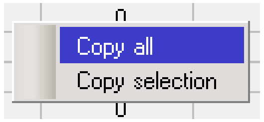
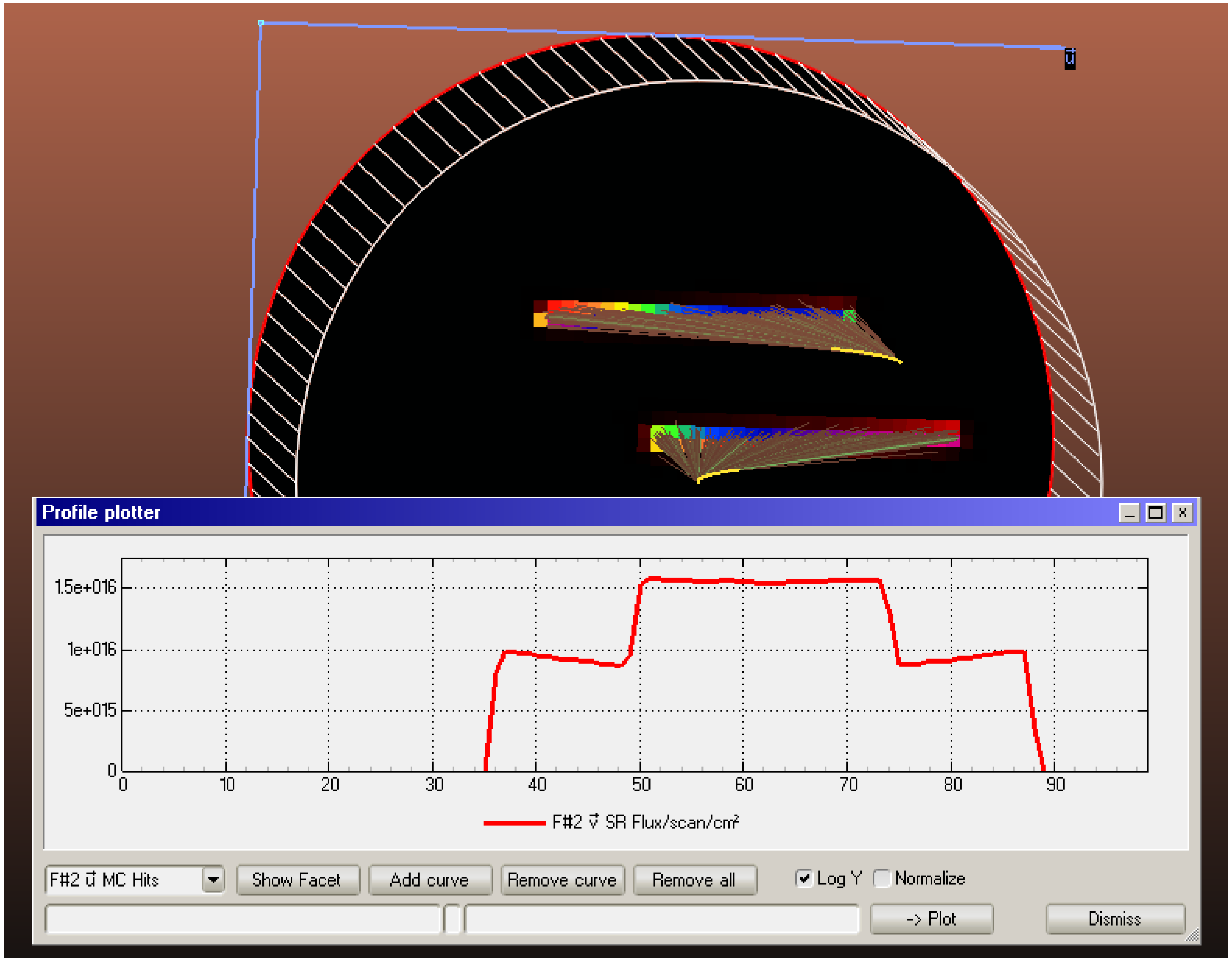



You can export the table for post-processing by copying it to the clipboard

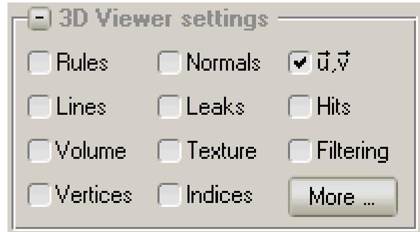
# Adding a profile

- Profiles split facets into 100 equal slices along their U or V local vectors. Flux and power are calculated for each slice.

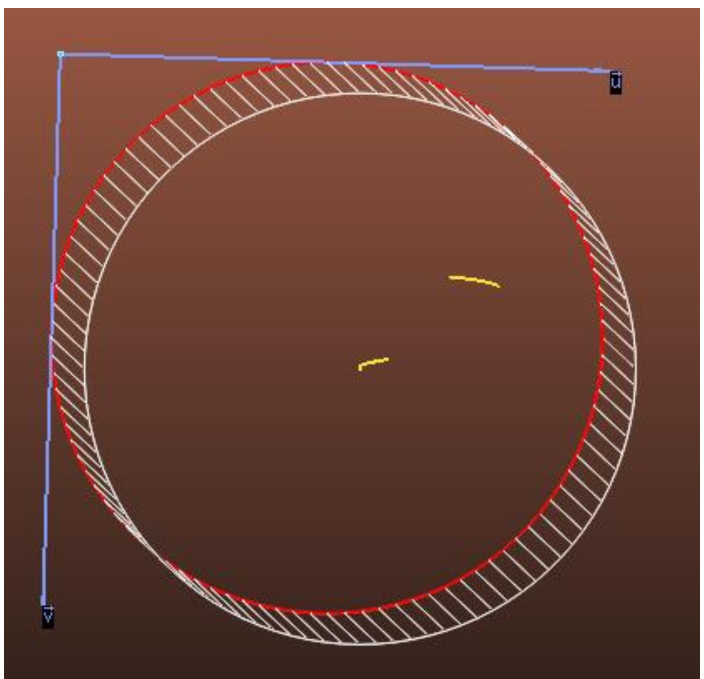


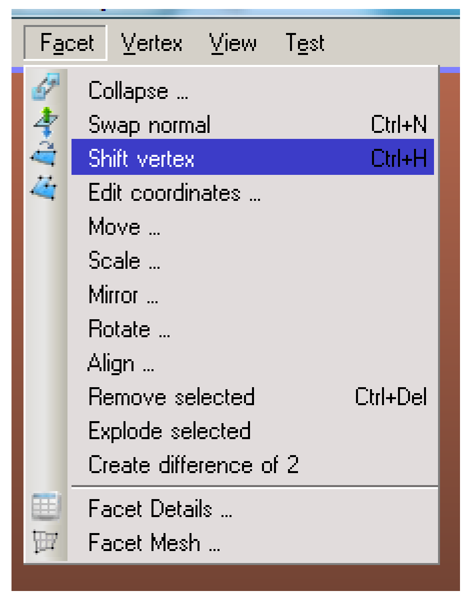
# Adding a profile

- Select a side facet, and turn on the "u,v" vector display in the viewer parameters:



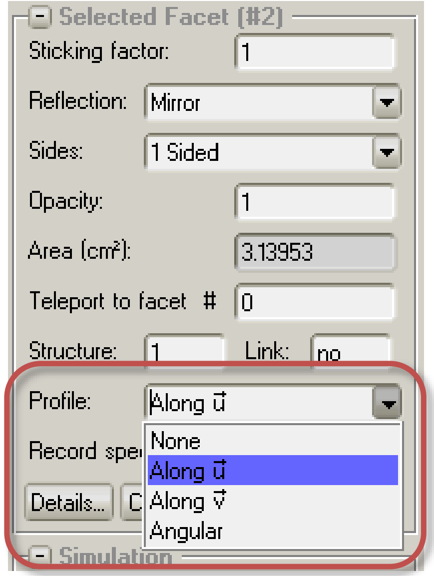

- The U and V vectors are visualized. (vector U points always from the first to the second vertex of a facet). You can rotate them by selecting *Shift Vertex* (CTRL+H) from the Facet menu



# Adding a profile

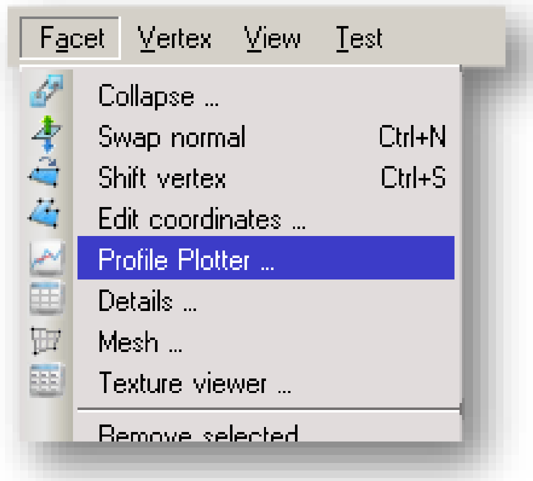
- Once the U or V vector points toward the direction you want to „slice" the facet, turn on a profile in facet parameters:




- Don't forget to click *Apply*. From now on Synrad will count profile values. Run the simulation for a while to collect values.

# Viewing the profile

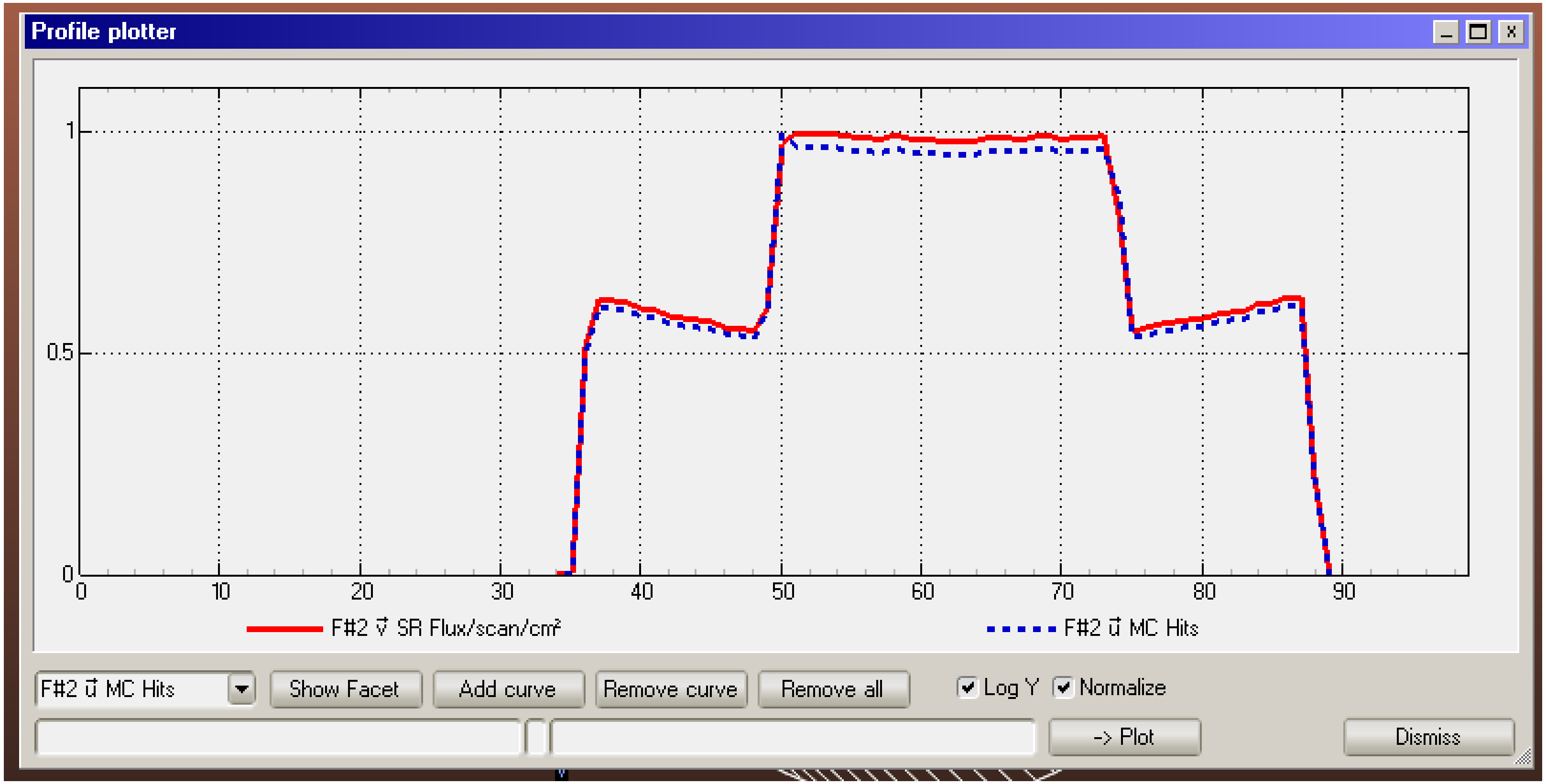
- To view the profile, open profile plotter:




- Then choose the profile you just set (bottom left), and click *Add Curve*

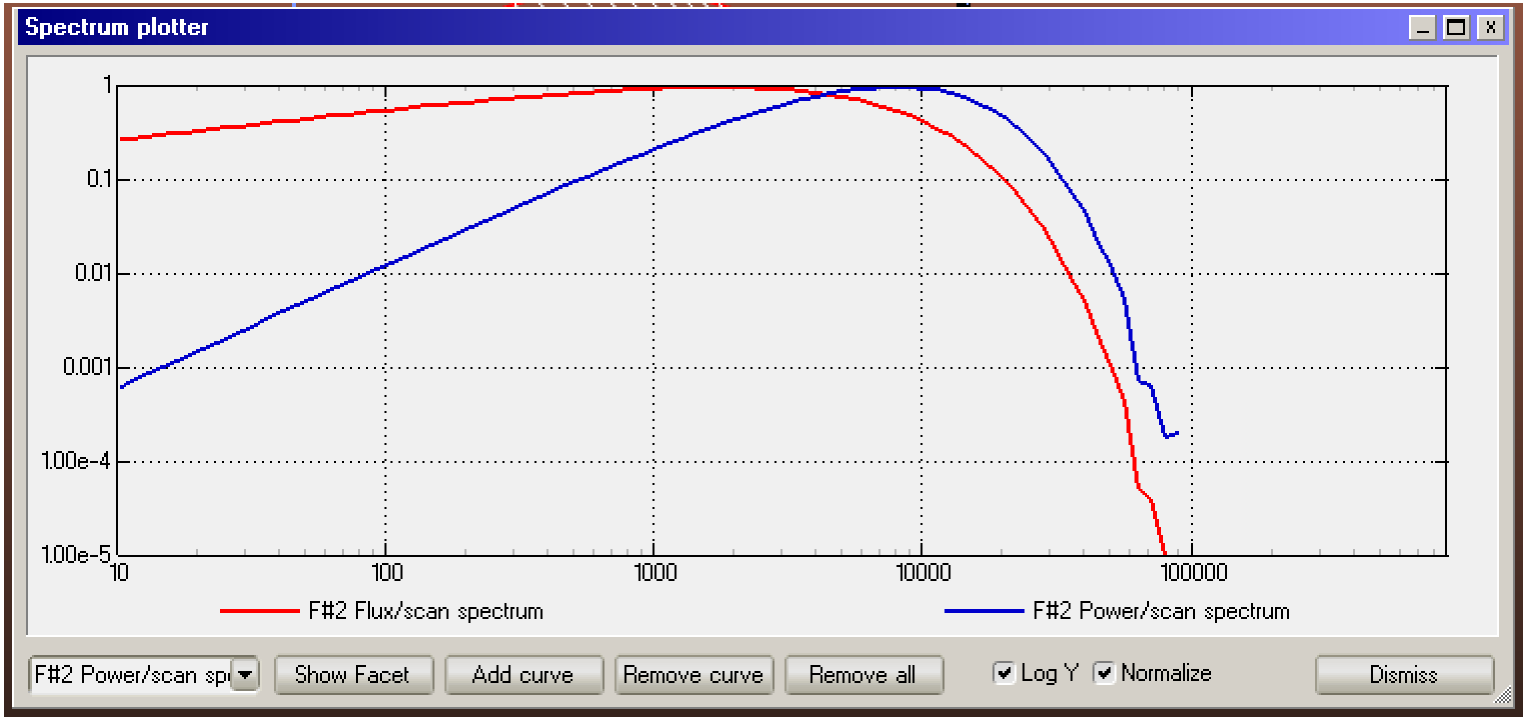
# Viewing the profile

- That's it. You can repeat the process and display several curves in the same plotter. (You can have unlimited facets with profile counting)



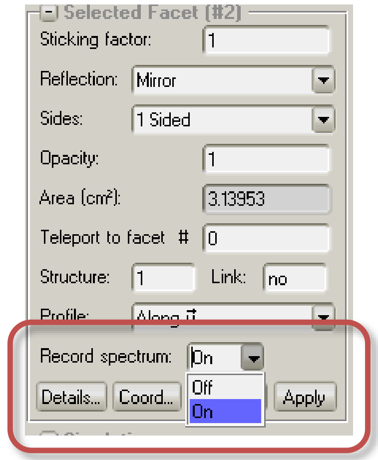
# Adding a spectrum

- Spectrums show the incident photons’ energy distribution.

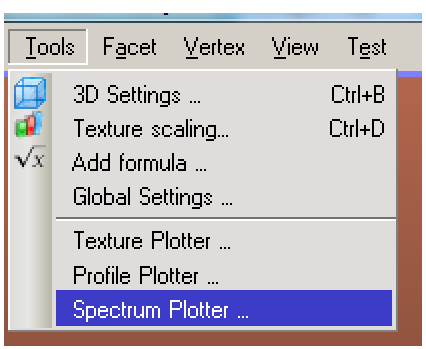


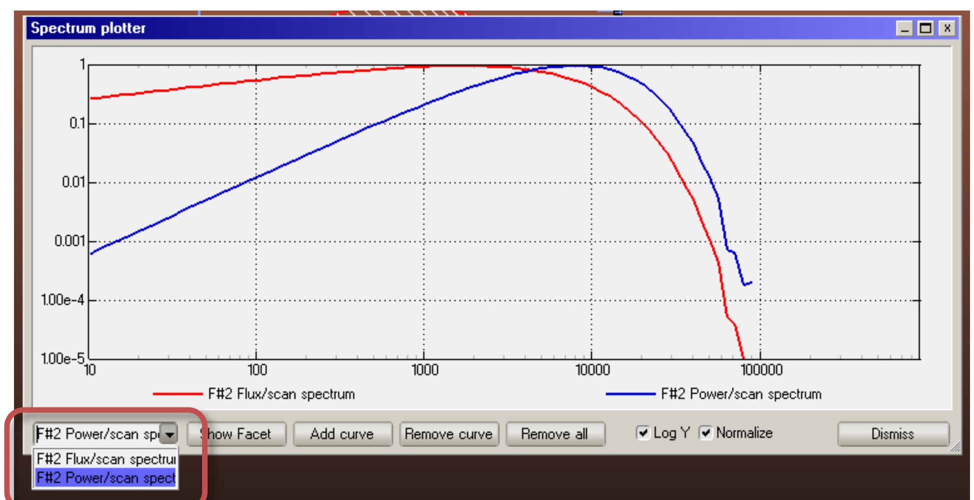
# Adding a spectrum

- They are added the same way as profiles: Select the desired facet, turn on *Record spectrum* in the parameters:




- Then open *Spectrum plotter* and add the curves you want to plot:



# The end

- Stuck at one point?
- Found a bug?
- Have a suggestion?

Tell your ideas on the website, where you can also find a video tutorial.

(http://cern.ch/test-molflow)