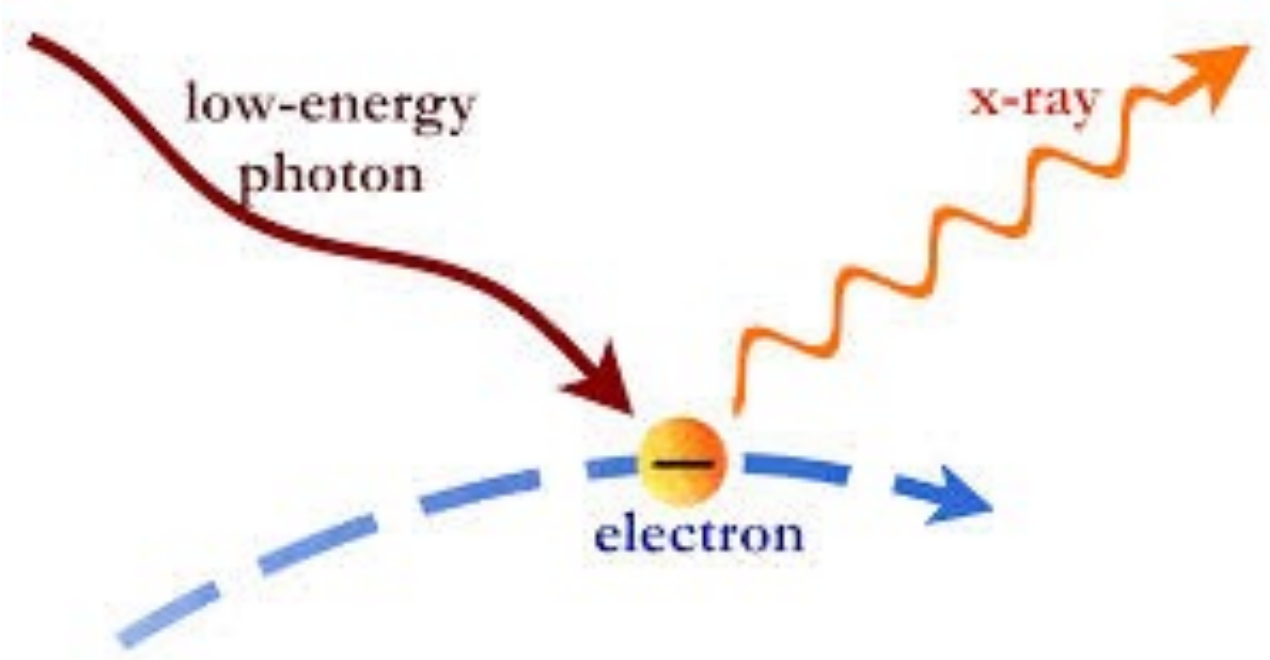
On Comptonization models

in the framework of WP4



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FP7 Strong Gravity Consortium meeting
Warsaw CAMK PAN 13-15/04/2016

MoCA in a nutshell

MoCA is a Monte Carlo code for Comptonization in Astrophysics
which includes polarisation

The code is written in Fortran95 (with Michal Bursa raytracing routine in C)
It works with single photons so it has no particular limits on the parameters of the model
It's modular and fully relativistic
Ray-tracing is punctual (A -> B)

Source can be point like emitting Wien spectrum or a Shakura-Sunyaev disc emitting a MTBB (Novikov-Thorne to be implemented).

Corona can have any slab/cylindrical or spherical geometry

It treats Comptonization but no reprocessing by the disc
Complete information can be registered for every photon

At the moment

The code with SR is well tested
The routines required for GR (Kerr metric, BL coordinates transformations, etc..) are already translated
Parallel transport of the polarisation vector still has to be tested

Outline

In the following we want to compare **MoCA** some of the most commonly used Comptonization models: ***compTT, compPS, Hardt model***

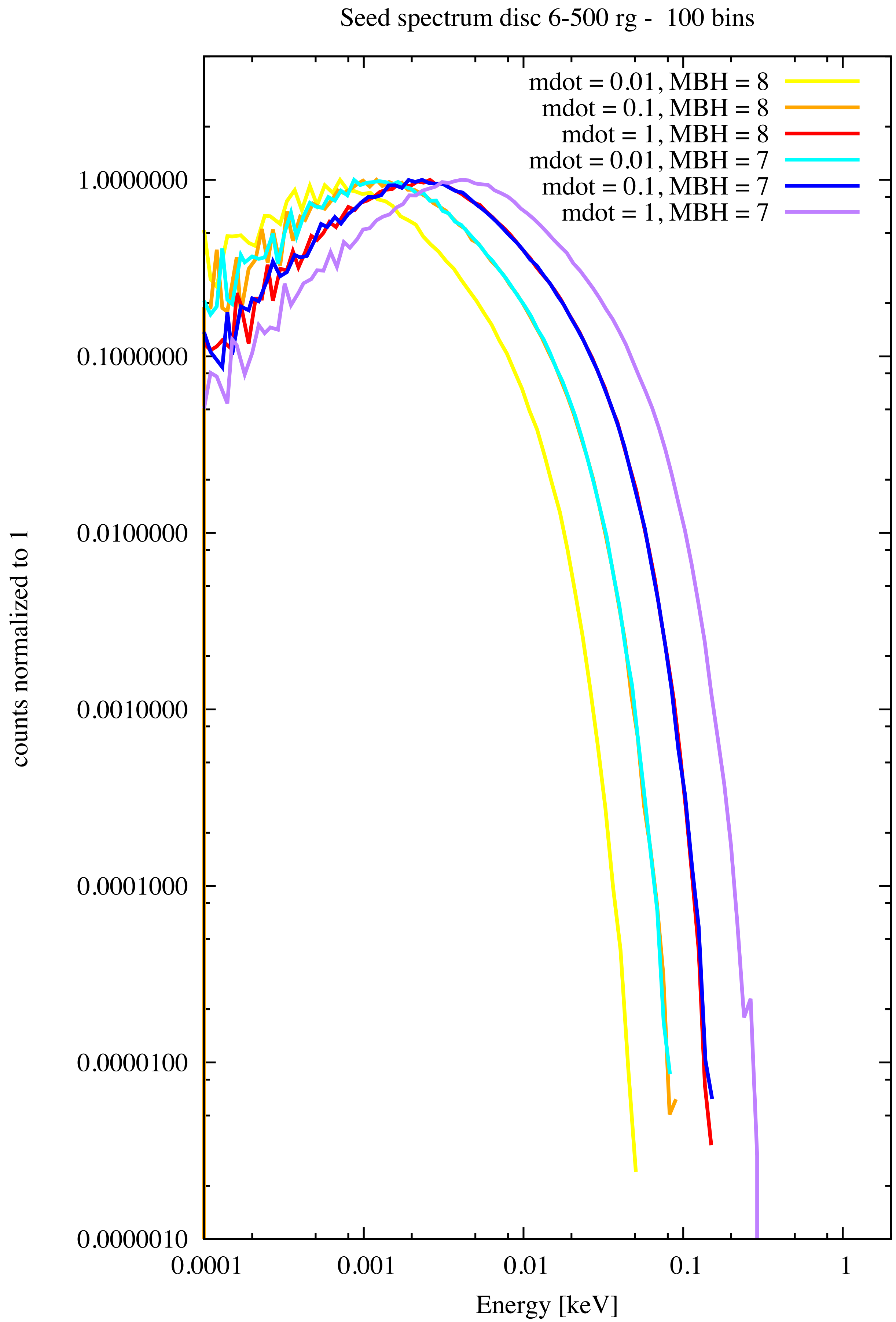
These models are:

- semi-analytical (i.e. they solve numerically radiative transfer equations)
- there's no black hole nor structured accretion disk *****
- the source emits a blackbody (i.e. single temperature) isotropically(?) *****
- special relativity is included but no general relativity

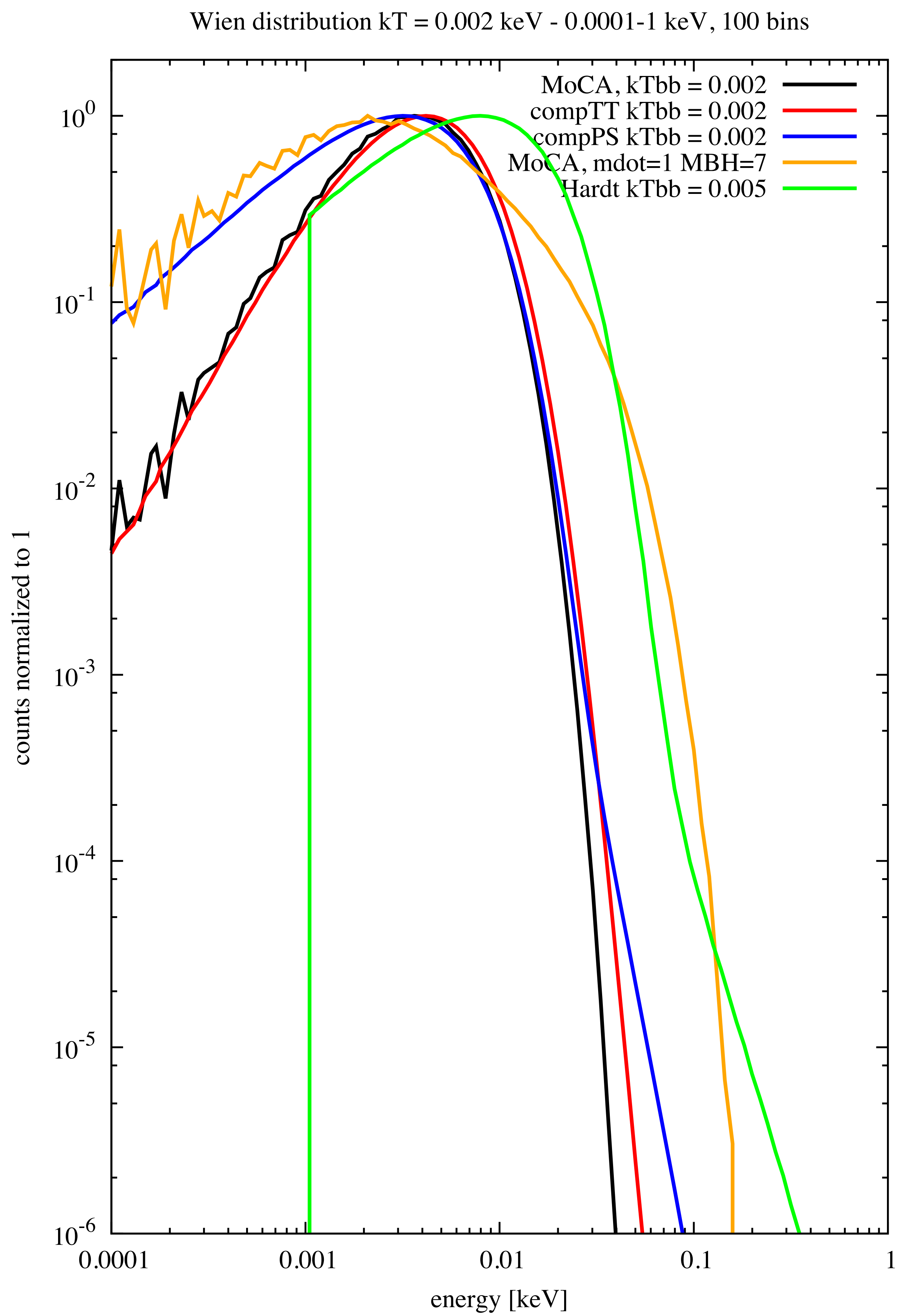
***** In compPS and Hardt model the source is a single-temperature disk (also multi-temperature for compPS) which injects the corona from below.

In compTT the source is point like for a SPHERICAL corona while it's a disc for a SLAB corona.
For all models it's not clear the emission law of the disc (i.e. radial emissivity/ spatial distribution of sources in the disc)

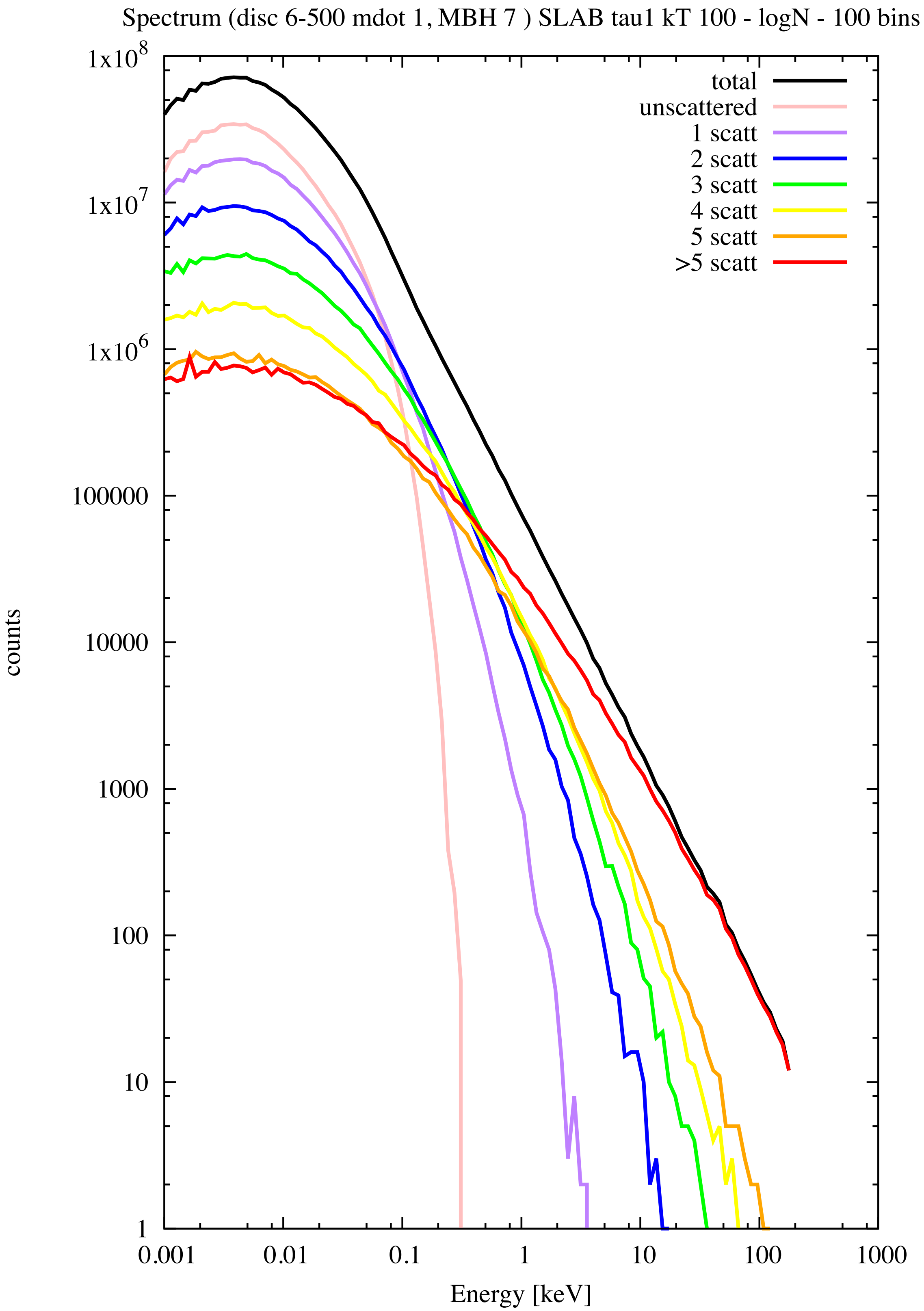
The MTBB spectrum in MoCA



The seed photons comparison



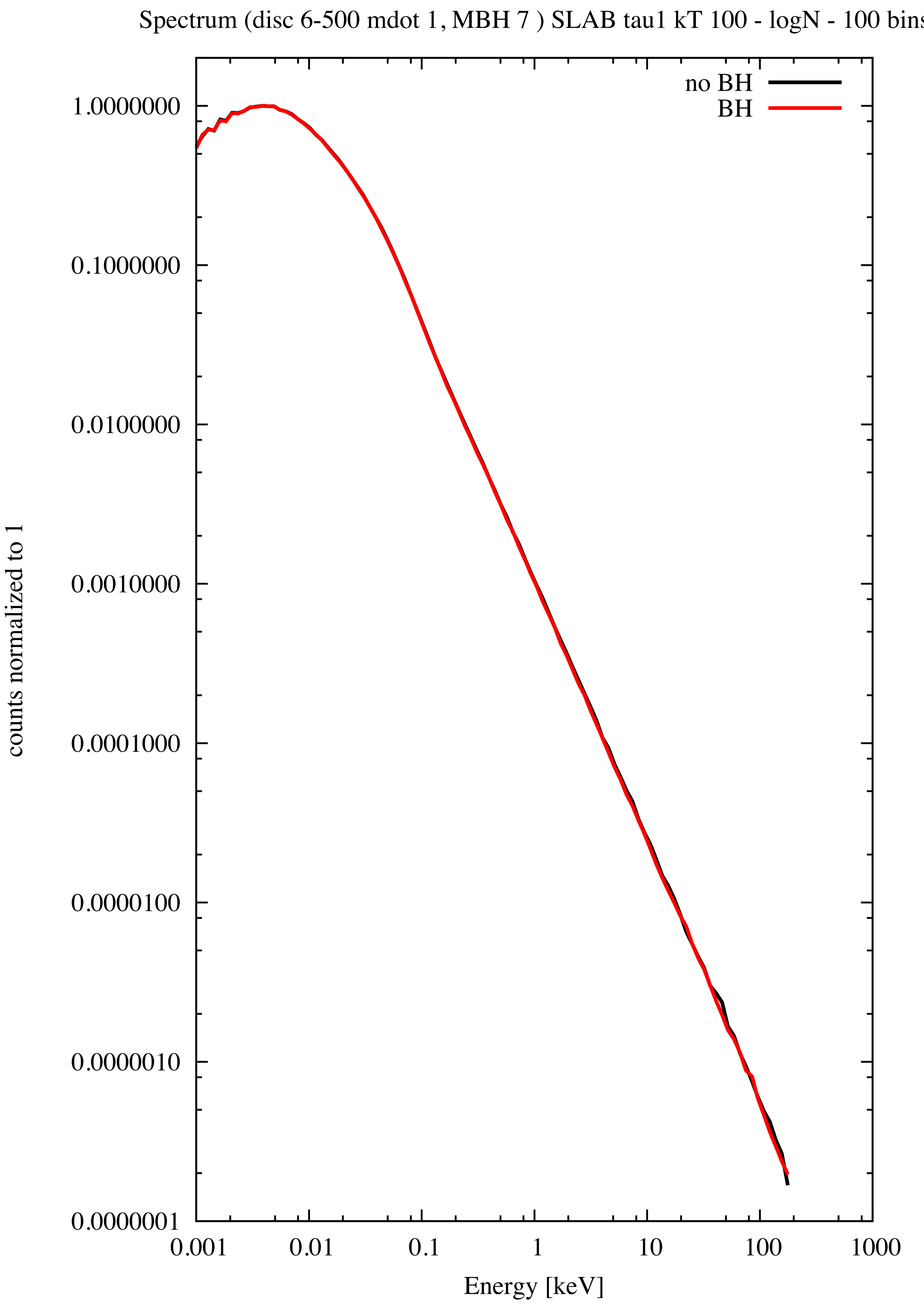
The Comptonized spectrum for the SLAB



In the plot on the left the decomposed spectrum for a **SLAB corona** with **kT = 100** keV and **tau = 1**

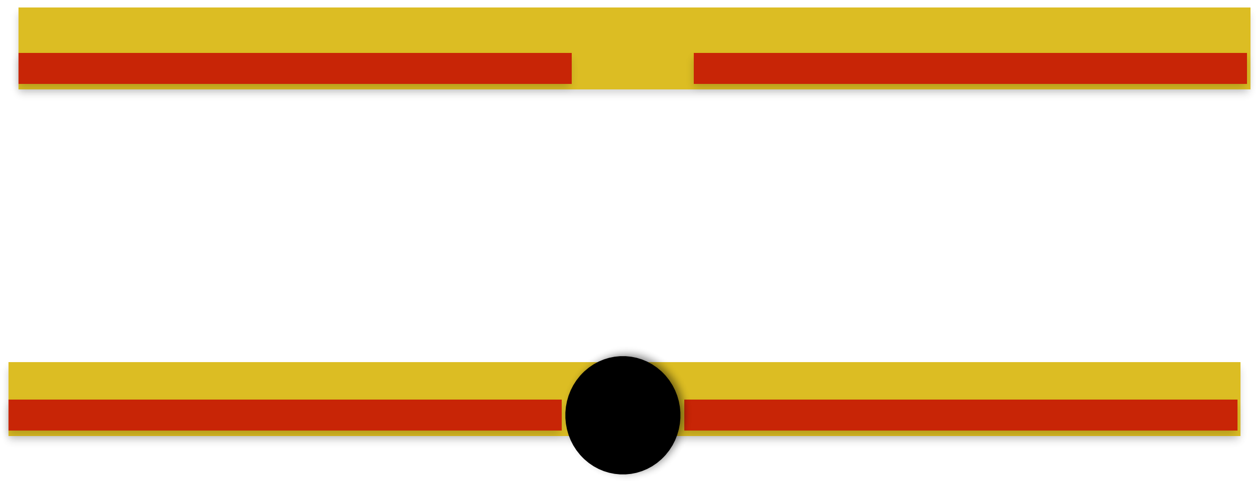
fallen onto disc	escaped	esc no scatt	esc with scatt
~75%	~25%	~30%	~70%

The SLAB corona model

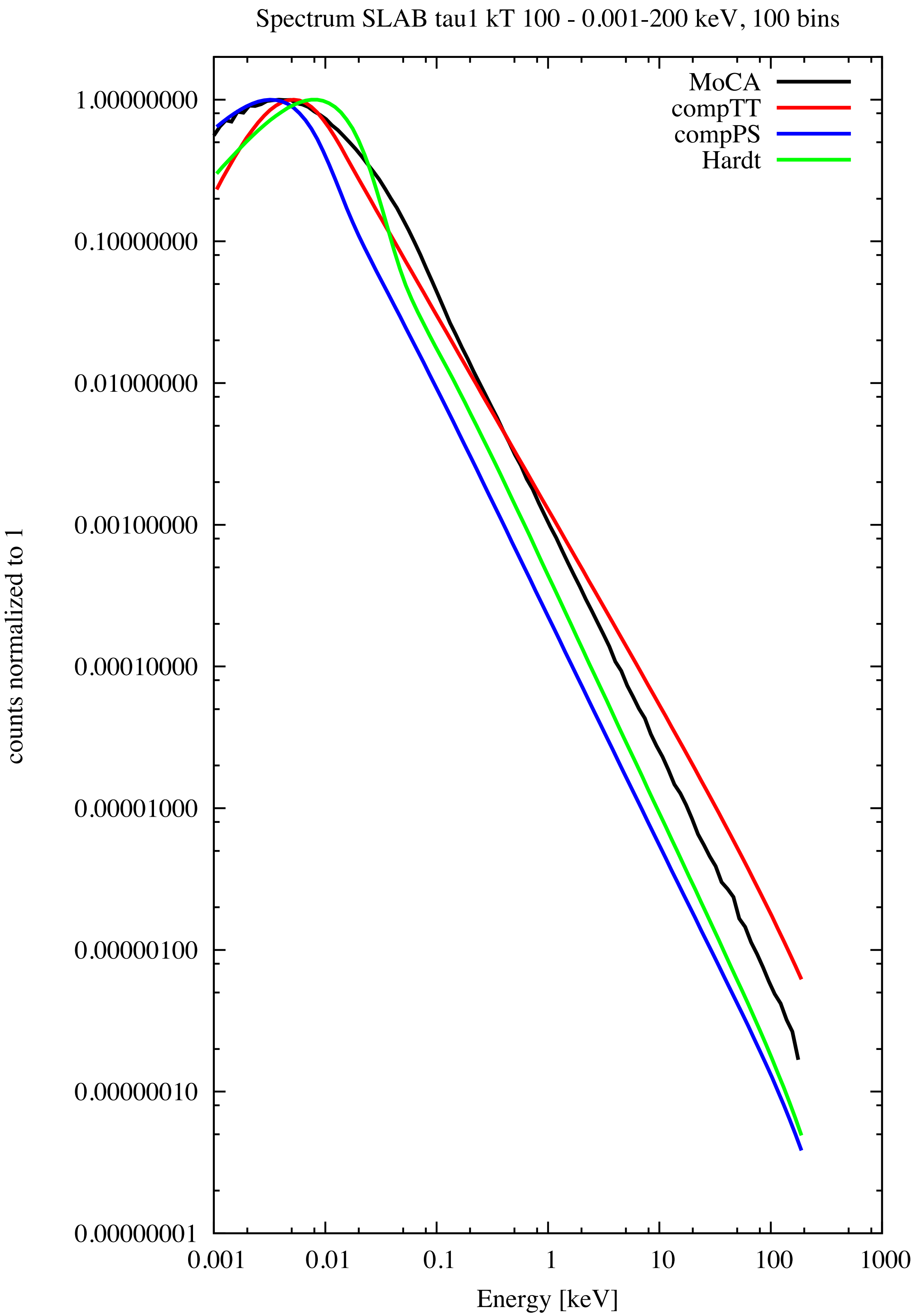


On the left the spectra obtained including or not the BH.

Below a sketch (not in scale) representing the two models, without and with the black hole



The Comptonized spectrum comparison

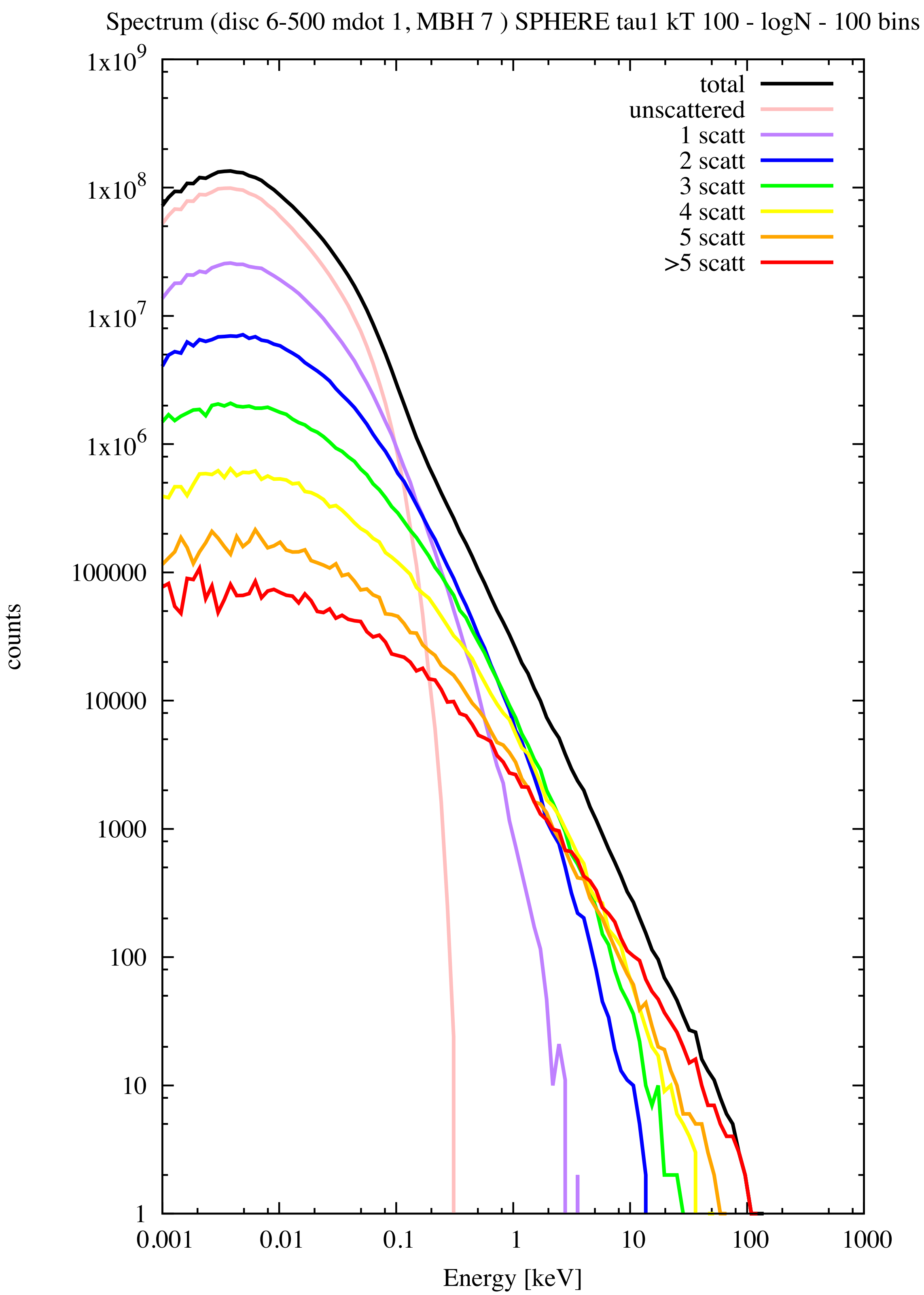


SLAB corona with **kT = 100** keV and **tau = 1**

Below we report the slopes from **2 to 80 keV**.

	MoCA	compTT	compPS	Hardt
Gamma	-1.62	-1.38	-1.61	-1.68

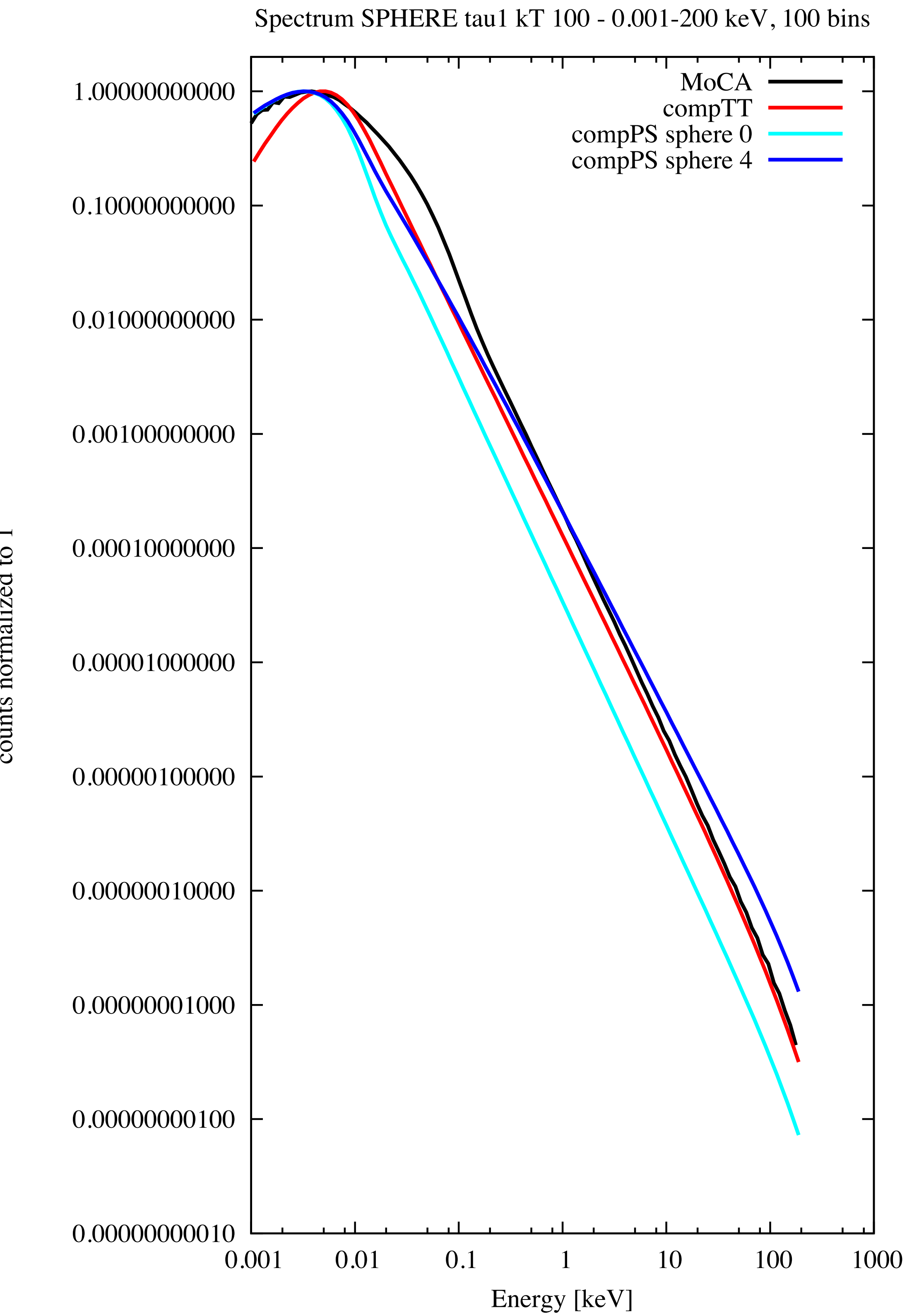
The Comptonized spectrum for the SPHERE



In the plot on the left the decomposed spectrum for a **SPHERICAL corona** with **kT = 100** keV and **tau = 1**

fallen onto disc	escaped	esc no scatt	esc with scatt
~67%	~33%	~60%	~40%

The Comptonized spectrum comparison



SPHERICAL corona with **kT = 100** keV and **tau = 1**

Below we report the slopes from **2 to 80 keV**.

	MoCA	compTT	compPS0	compPS4
Gamma	-1.94	-1.87	-1.96	-1.75

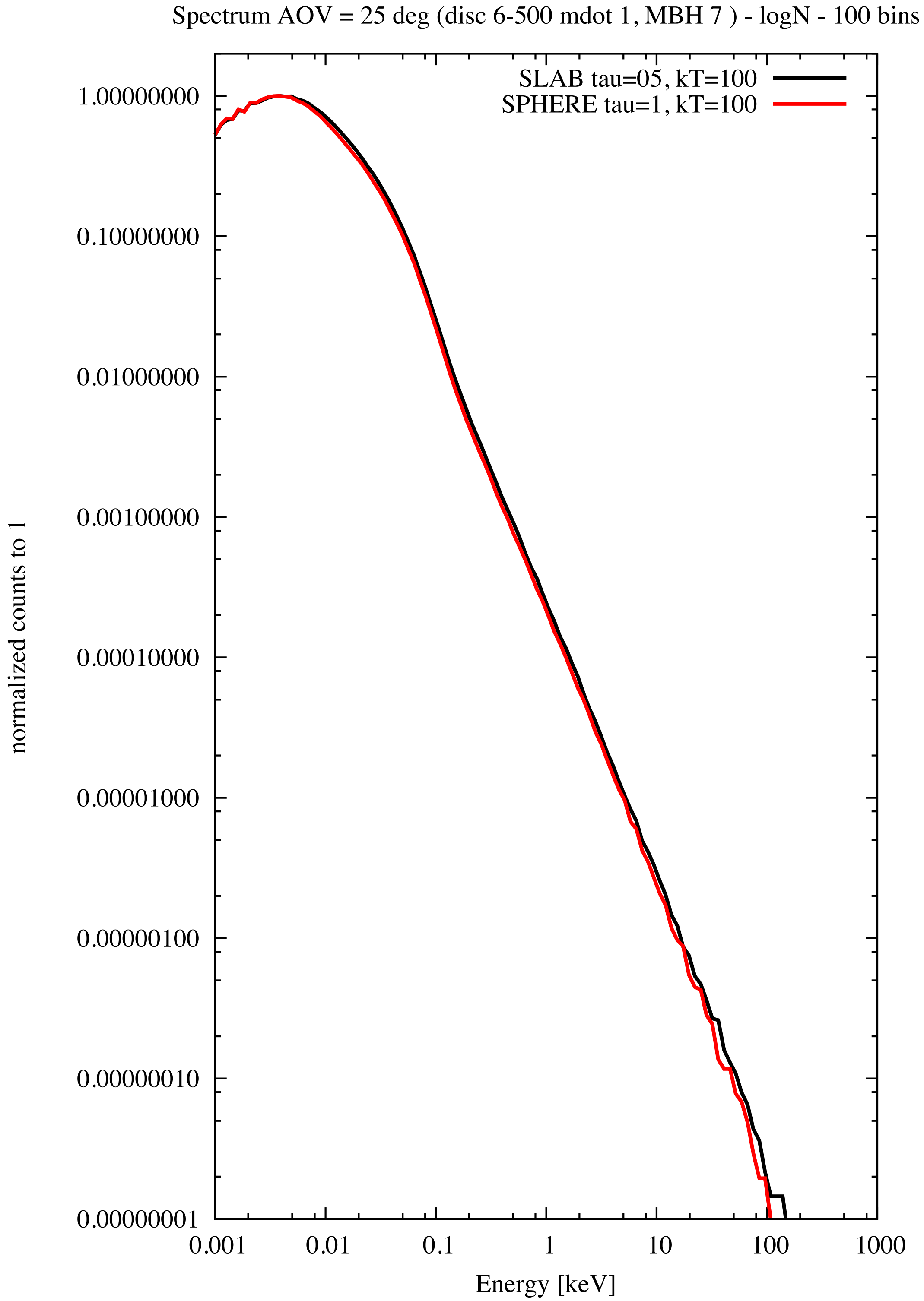
Below a summary of the fitted slopes for the different models for all the investigated scenarios. All the slopes are fitted between 2 and 80 keV unless differently specified

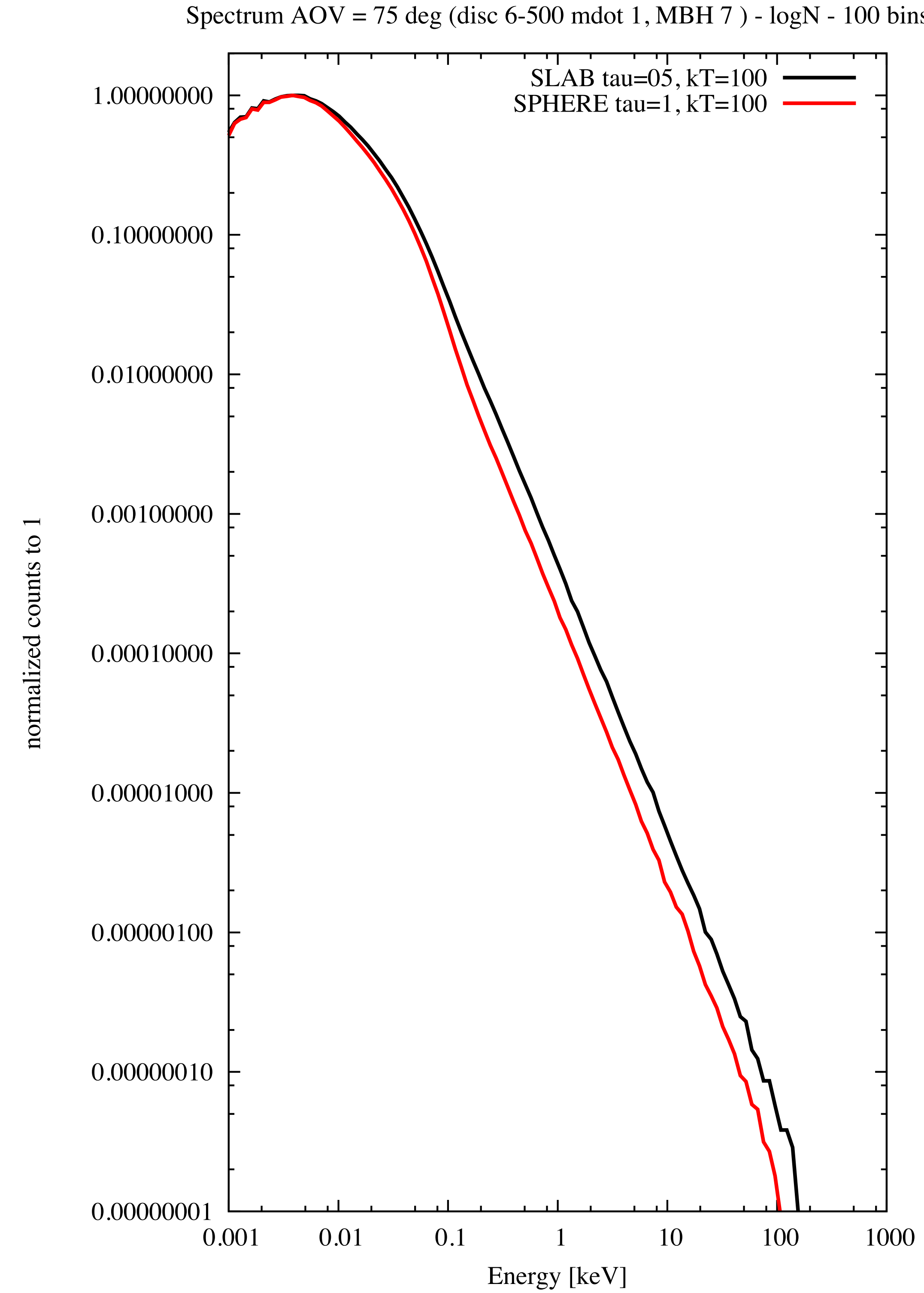
	MoCA		compTT	compPS	Hardt
SLAB 1-100	-1.63		-1.38	-1.61	-1.68
SLAB 0.5-100	-1.95		-1.63	-1.97	-2.02
SLAB 1-50	-2.31		-1.67	-2.08	-2.11
SLAB 0.5-50	-2.79 (2 - 40)		-2.06	-2.50	-2.56
	MoCA disc	**MoCA point**	**compTT**	**compPS0**	**compPS4**
SPHERE 1-100	-1.95	-1.82	-1.88	-1.96	-1.76
SPHERE 0.5-100	-2.28 (2 - 40)	-2.19	-2.33	-2.38	-2.17
SPHERE 1-50	-2.57 (2 - 12)	-2.63 (2 - 40)	-2.44	-2.59	-2.32
SPHERE 0.5-50	-3.29 (2 - 8)	-3.06 (2 - 8)	-3.12	-3.20	-2.93

The trends are right: the slope become steeper as the thermal energy of the corona and the optical thickness decrease.

MoCA gives similar results to compPS while compTT gives flatter spectra in all the scenarios

The spectra face-on and edge-on





SLAB 0.5/100	SPHERE 1/100
-1.94	-1.99

SLAB 0.5/100	SPHERE 1/100
-1.89	-1.94

Conclusions

The reason for compTT flatness in the spectra remains obscure.

compPS works fine but weirdly the more accurate approach for the spherical case (geom = 4) produces spectra which are in most of the cases different from those produced by all the other models

These studies represent also a solid base to verify the results obtained with General Relativity in the code (for both the spectra and the polarisation signal)

Future work

Explore the space of parameters which are not allowed by these models and produce models for WP3 (NuSTAR energy cut-off)

Compare polarisation results with Stokes

Run the code with GR and polarisation (deliverable 4.2 in WP4)

Couple MoCA with a more accurate disc code (i.g. SlimDisc) and a reprocessing code (new Stokes) to produce self-consistent simulations (WP10-11)