Trigger Efficiency for PRad Experiment

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1 Introduction

The trigger efficiency study was performed using photon tagged data at 1GeV before the physics data taking of the PRad experiment between May 29, 2016 and May 31, 2016. It uses the runs: 889, 890, 893, 894, 895, 896, 916, 918, 919, 923, 924, 925, 926, 927, 928, 929, 932, 933, 934, 935, 946, 947, 948, 949, 950, 951, 952, 953, 955, 956, 957, 958, 960, 961, 962, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979; each runs for a certain set of HyCal modules (module_run_calib.txt). This study required the alignment of the tagger channels to extract the reconstructed energy of the tagger and the calibration of HyCal using both reconstructed of HyCal energy and Energy of tagger.

2 Selection

These selection cuts are performed in order to clean the data sample from noise and be sure that the event in the tagger corresponds to the hit in HyCal.

- only 1 hit in tagger and 1 hit in HyCal
  → at low energy, there can be several events reconstructed in the tagger, they are then hard to identify with HyCal hits.

- $E_{HyCal} > 200\ MeV$
  → below this energy, the tagger E channel become to noisy

- $|x_{HyCal} - x_{transporter}| < 15\ mm$
  → this cut is performed to avoid photons from the halo, which create some noise. It corresponds to $\sim 1\sigma$ of the distribution Fig. 1. The variable $x_{transporter}$ is extracted using the files transporter_time_position_#run_number.txt that follows time linearly the transporter movement.

- $|t_{tagger} - t_{HyCal} - t_{offset}| \leq 25ns$
  → This cut is performered to insure the matching of HyCal and the tagger. It also correspond with 1σ of the distribution Fig. 2. The variable t_{offset} is different for each run and each trigger, it is given in the file tagger_timings.txt (columns 1, 4 and 7).

- $|E_{HyCal}/E_{tagger} - 1| < 3\sigma_{E_{HyCal}/E_{tagger}}$
  → This cut removes events badly reconstructed in the tagger Fig. 3

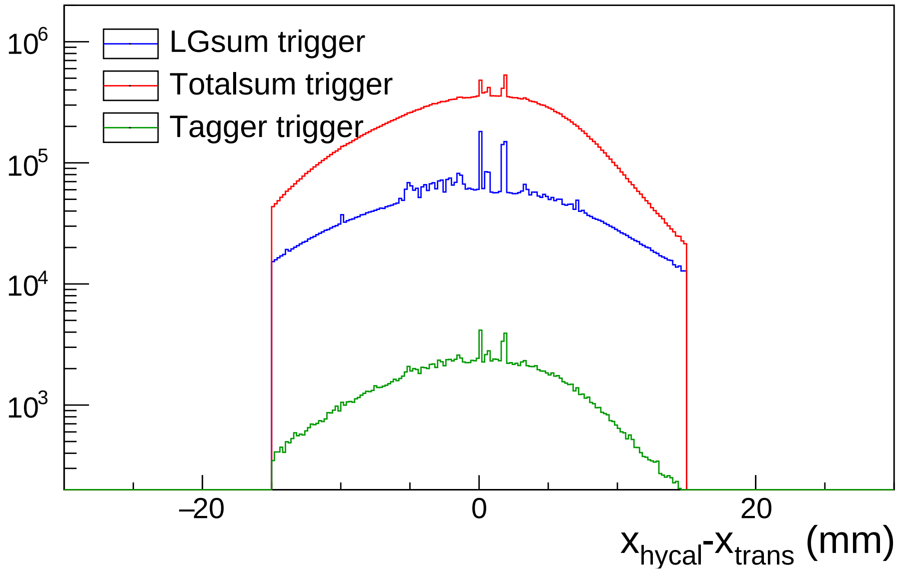

Figure 1: Difference of position between the transporter and the reconstructed hit in HyCal

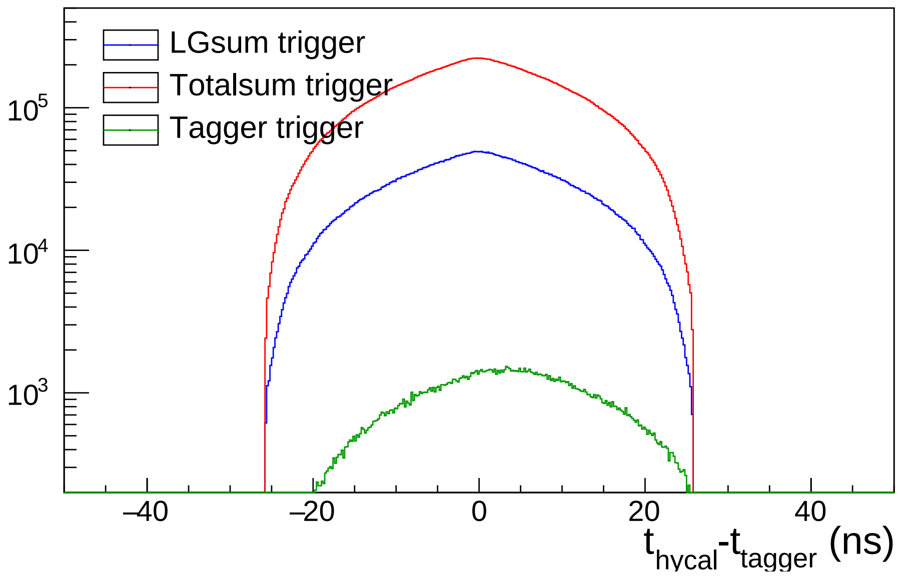

Figure 2: Difference of timing between the tagger and the hit in HyCal

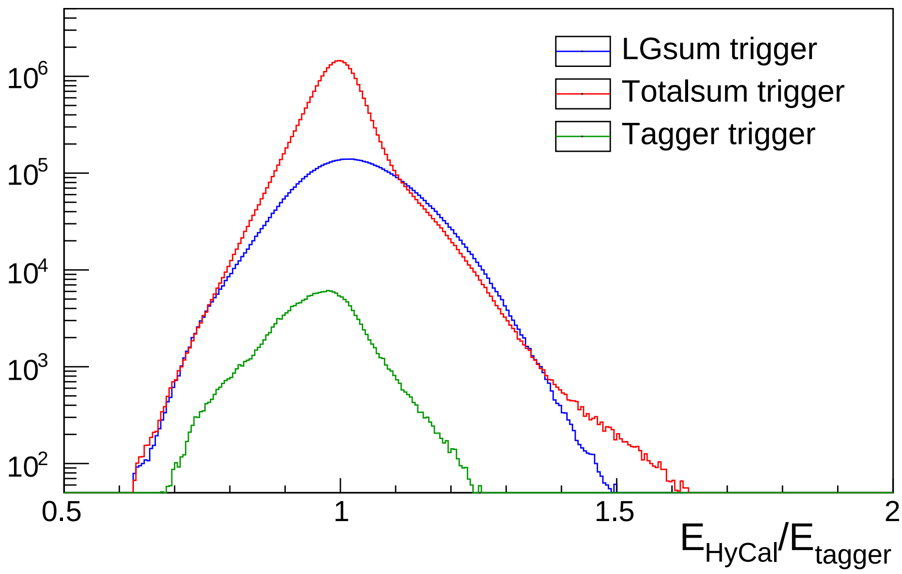

Figure 3: Elasticity between tagger energy recontruction and HyCal energy reconstruction

3 Module Trigger Efficiency

After this thorough selection, the efficiency can be extracted module by module. Some modules are known to have a dead dinode or anode, or both. Since the beam was not particularly stable during the calibration data taking, some modules lack also some statistics to extract the efficiency. All these modules are identified in the Tab. 1, and for the practical efficiency table, the value given corresponds to the average of the surrounding modules. Due to some missing tagger channels during the data taking, the efficiency for the modules between W478 and W749 can only be extracted below 650 MeV.

	modules name
dead	G900, W824, W835, W891
lack statistics	G10, G101, G102, G129-G136, G159, G393, G394, G783, G784, G793-G795, G813, G820, G832, W393, W419, W420, W470-W472, W527, W528, W560, W563, W629, W630, W637, W752

Table 1: Table of modules without trigger efficiency extraction

For all the other modules, the trigger efficiency is calculated as the ratio of events triggered by any HyCal trigger (LGsum $\vee$ TotalSum) over all the trigger events (LGsum $\vee$ TotalSum $\vee$ Tagger):

$$\epsilon = \frac{N_{LGsum} + N_{Totalsum}}{N_{LGsum} + N_{Totalsum} + N_{Tagger}} \quad (1)$$

This efficiency has been calculated in 17 bins of E_{tagger} (200 MeV $\leq E_{tagger} \leq$ 1050 MeV). From this one can extract a plateau efficiency which starts from 500 MeV as you can see on Fig.4. The inflexion and lower statistics around 700 MeV is due to some missing TChannels.

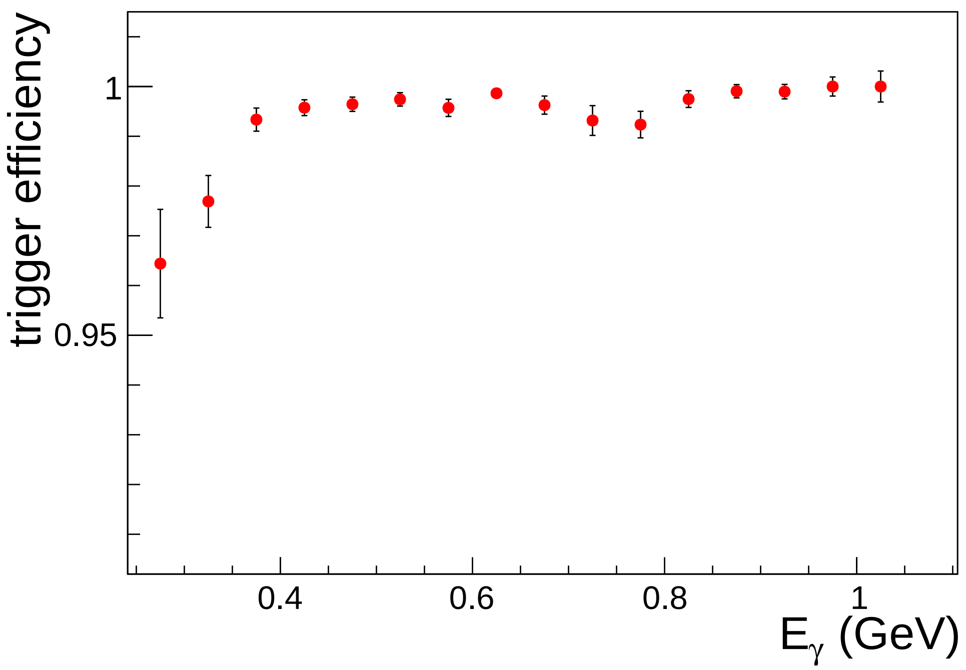

Figure 4: Trigger Efficiency for the module W460

4 Normalization by Period

Before showing any map of the trigger efficiency, you can notice on Fig. 5 that the efficiency is highly non uniform on HyCal. There is no particular angle dependency so this non uniformity comes from changes in the beam quality, in the DAQ settings of from the missing Tagger channels.

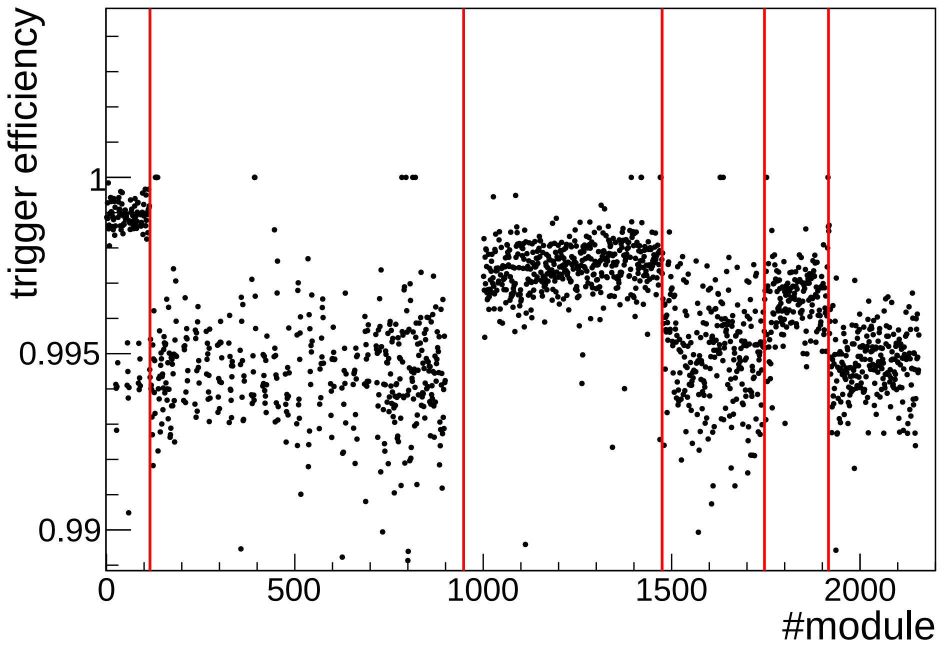

Figure 5: Trigger efficiency before non uniformity correction versus module number

In order to cope for this non uniformity, the modules have been divided into different period of data taking (Tab.2). The distribution of plateau efficiency is then fitted to extract and average and a width of the efficiency distribution (Fig 6).

period	modules	runs
1	G1 - G115 $\wedge$ PbGlass top sector	889 - 896
2	W1 - W476	916 - 935
3	W477 - W748	946 - 953
4	W749 - W918	955 - 960
5	W919 - W1156	961 - 969
6	other PbGlass	970 - 979

Table 2: Periods of data taking

The efficiency is then shifted and smeared according to the last periods of data taking (periods 5 and 6), that are stable for both PbGlass part and $PbWO_4$ part with an average at $<\epsilon>= 0.995$ and a standard deviation at $\sigma_\epsilon = 0.001$.

$$\epsilon_{module\, corr} =<\epsilon> + \frac{\sigma_\epsilon}{\sigma_{\epsilon\, period}} \cdot (\epsilon_{module} - <\epsilon>_{period}) \tag{2}$$

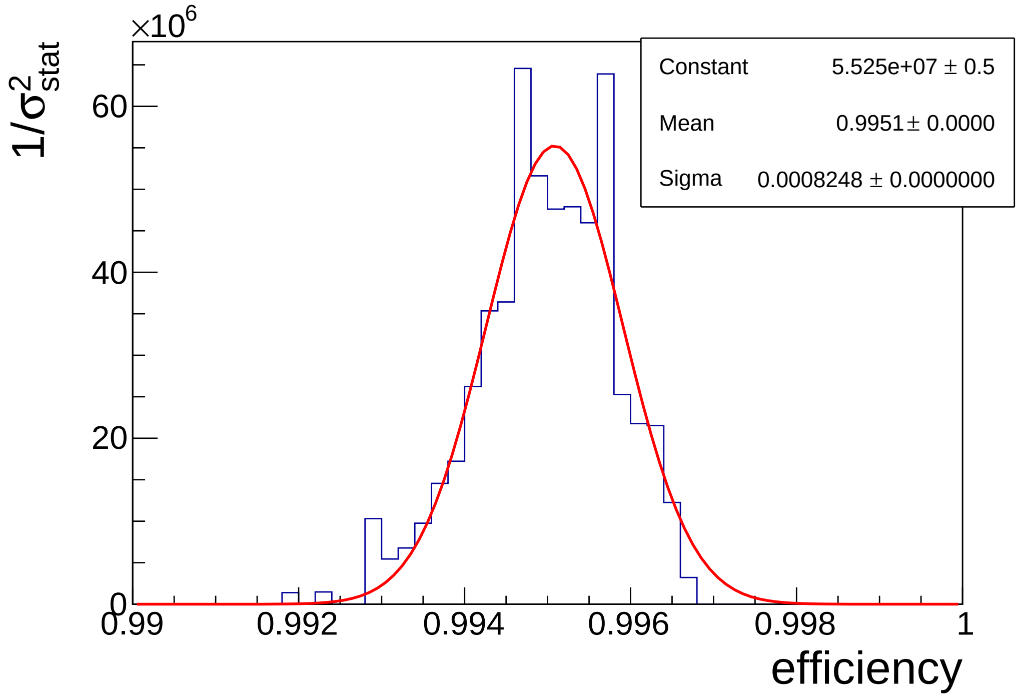

Figure 6: Fit of trigger efficiency distribution for each period

As a result, one gets a uniform trigger efficiency (Fig. 7,8)

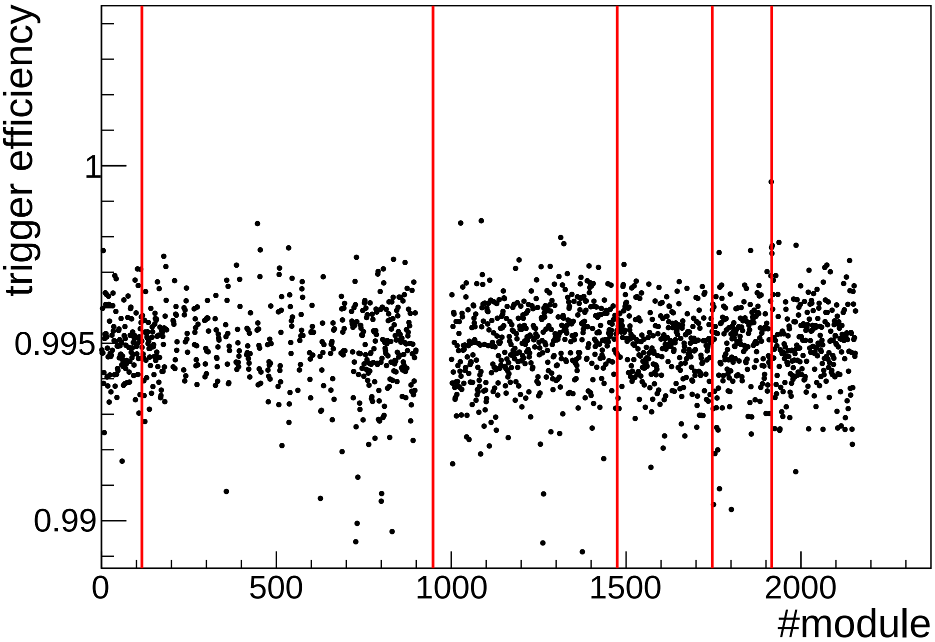

Figure 7: Trigger efficiency after non uniformity correction versus module number

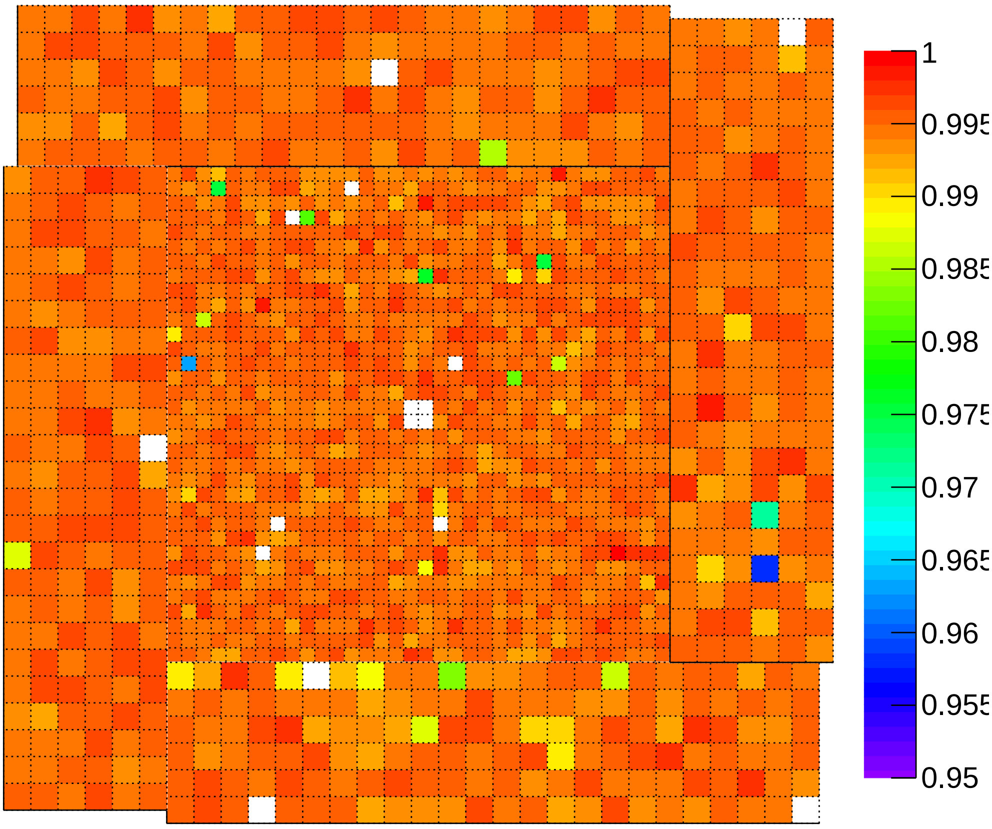

Figure 8: Trigger efficiency map after non uniformity correction

5 Trigger Efficiency by regions

To give a clearer idea of the dependency of the trigger efficiency versus the incident photon energy, modules were grouped by regions (PbGlass, $PbWO_4$, transition) to accumulate statistics. These trigger efficiencies are shown on Fig. 9.

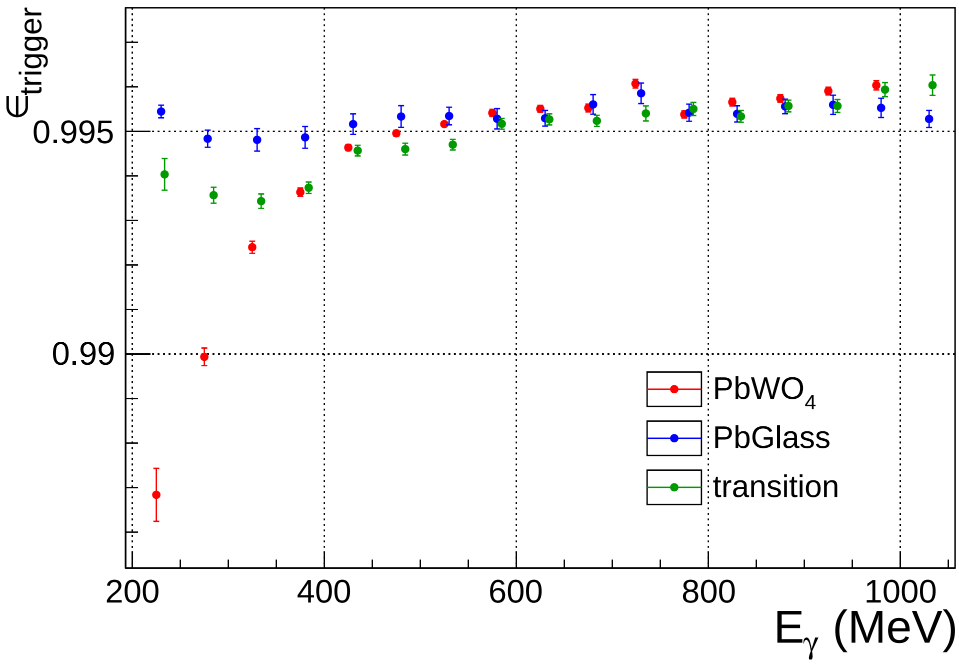

Figure 9: Trigger efficiency map after non uniformity correction

To take into account the energy dependency of this trigger efficiency into the simulation, these curves have been fitted by regions (Fig. 10, Eq. 5). All these informations are synthesized in the file hycal_trgeff_regions.txt module by module.

$$\epsilon_{PbWO_4} = \epsilon_{module} \cdot (1 - exp(-9.7003 \cdot E(GeV) - 2.5097) \quad (3)$$

$$\epsilon_{PbGlass} = \epsilon_{module} \cdot (1 - exp(-0.6977 \cdot E(GeV) - 6.8115) \quad (4)$$

$$\epsilon_{transition} = \epsilon_{module} \cdot (1 - exp(-2.6147 \cdot E(GeV) - 5.164) \quad (5)$$

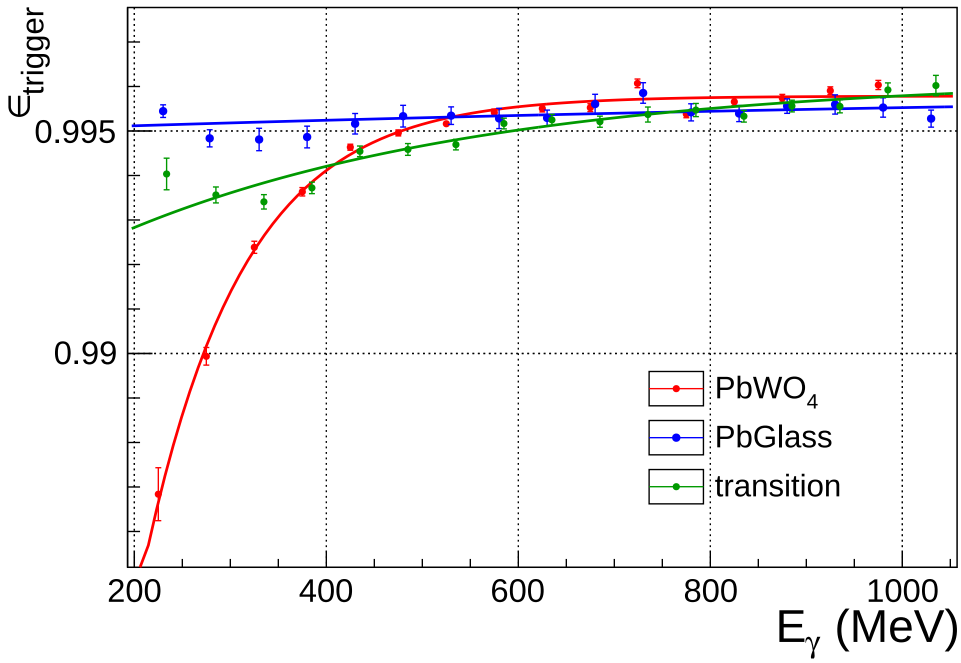

Figure 10: Trigger efficiency map after non uniformity correction