The CMS High Level Trigger

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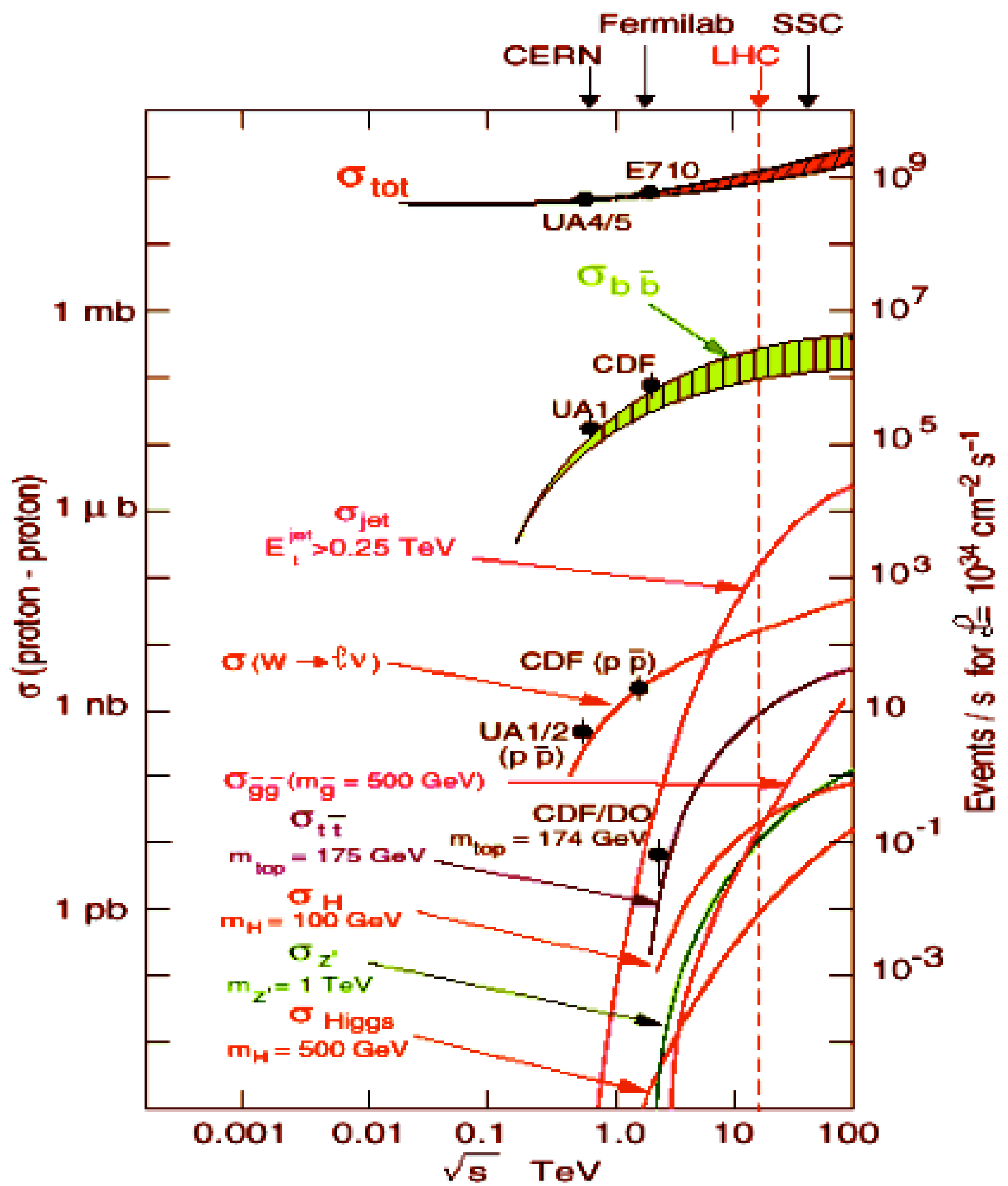
Why do we need a trigger?

Collision rate at the LHC is
heavily dominated
by large cross section
QCD processes
not interesting
for the physics program of CMS.
Interesting physics has rates <10Hz

Not possible to write all the events
and select later on.
Final bandwith limited!

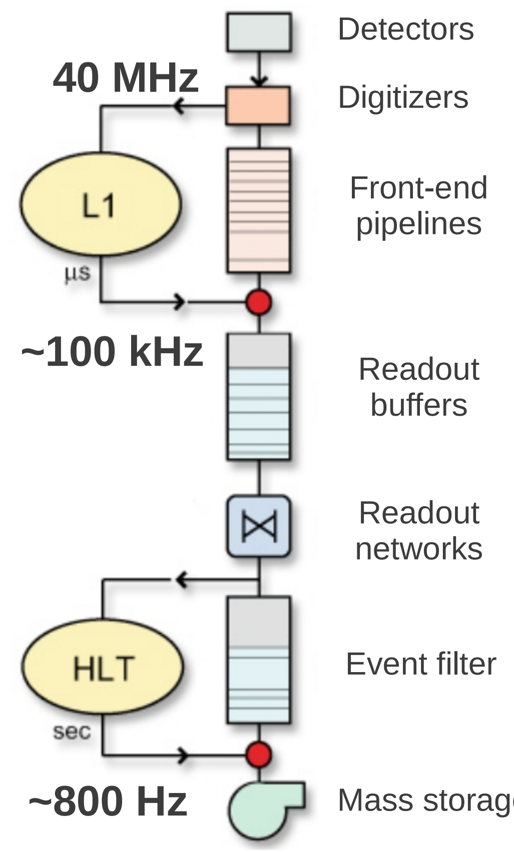
Physics driven choices!



… Looking for a needle in a haystack

The CMS experiment features a **two-level trigger**:

- first level (L1), hardware, selecting events to a maximum rate **~100 kHz**
  This upper limit is imposed by the CMS data acquisition electronics
- High Level Trigger (HLT), software, further reducing the rate to **~800 Hz**
  on average, for offline data storage on local disk or CMS Tier-0, of which:
  - an average rate of 400 Hz for prompt reconstruction within 48h (“core”)
  - an average rate of 400 Hz for reconstruction in 2013 (“parking”)



L1: uses the information from the calorimeters and the muon chambers
HLT: starting from the L1 candidate, exploits also the tracker information

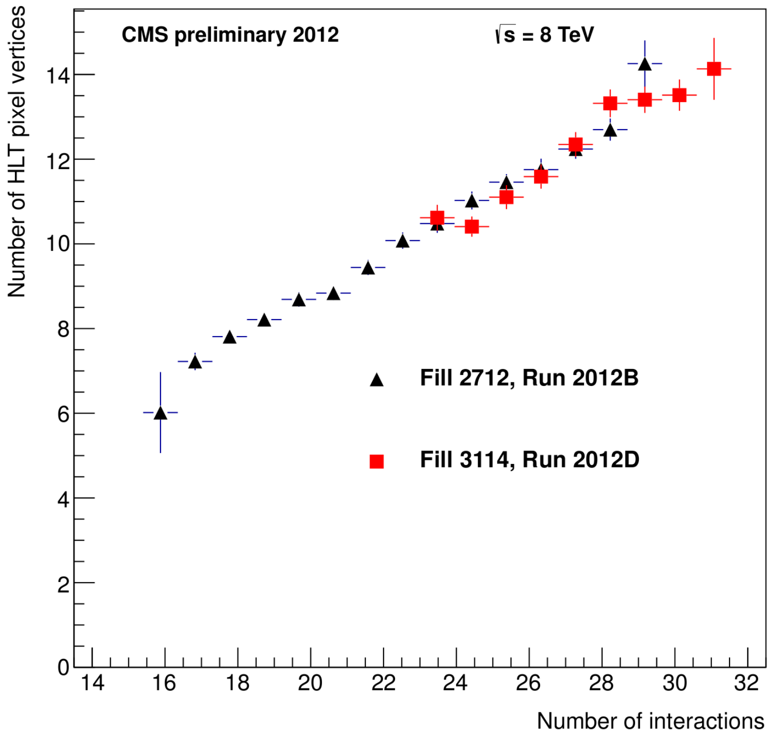
Each HLT trigger path is a sequence of reconstruction and selection steps of **increasing complexity**.
Information from calorimeters and muon detectors reduces the rate before tracking reconstruction (CPU expensive!) is performed.

The CMS High Level Trigger

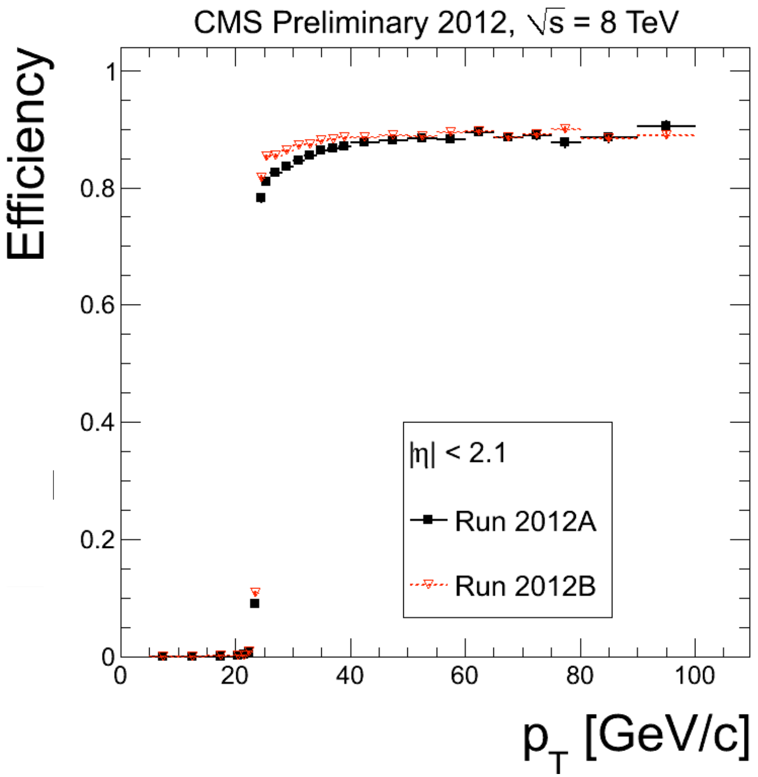
- aims to maximize ***efficiency*** while keeping ***CPU-time*** and ***rate*** low
- its algorithms use the ***same software framework*** and most of the same ***reconstruction code*** used for ***offline*** reconstruction and analyses
- must be ***flexible*** to adapt to changes in data-taking conditions, like changes in luminosity or special conditions occurring during the CMS commissioning or dedicated LHC fills
- must provide on-line ***detector monitoring*** (→specific trigger paths for calibration and alignment)
- its performance should be ***robust*** with respect to changes in alignment and calibration constants
- should be stable with respect to ***pile up***
- must work within a ***peak CPU time***: 200 ms/evt @ 100 kHz input rate

Vertex reconstruction

Muon reconstruction

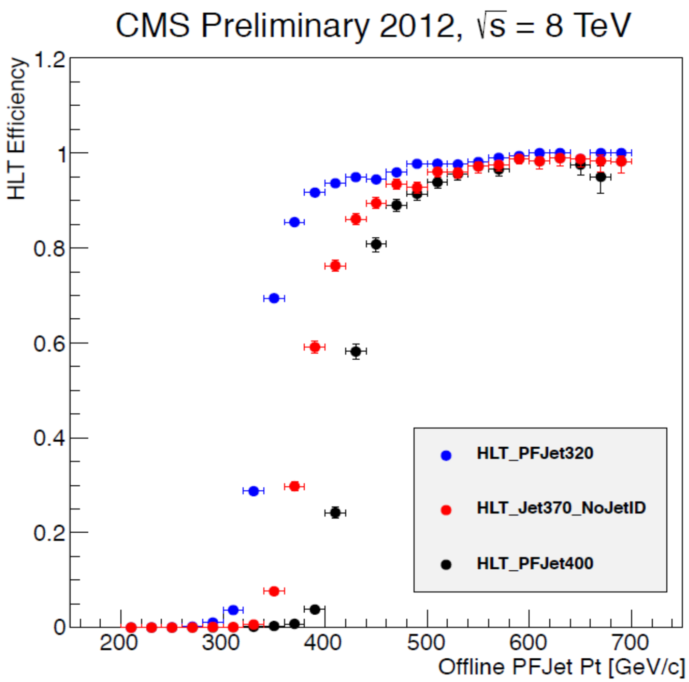


Number of pixel vertices
reconstructed at HLT.
The number of interactions is calculated from
the bunch luminosity as measured by
the forward calorimeters (HF).



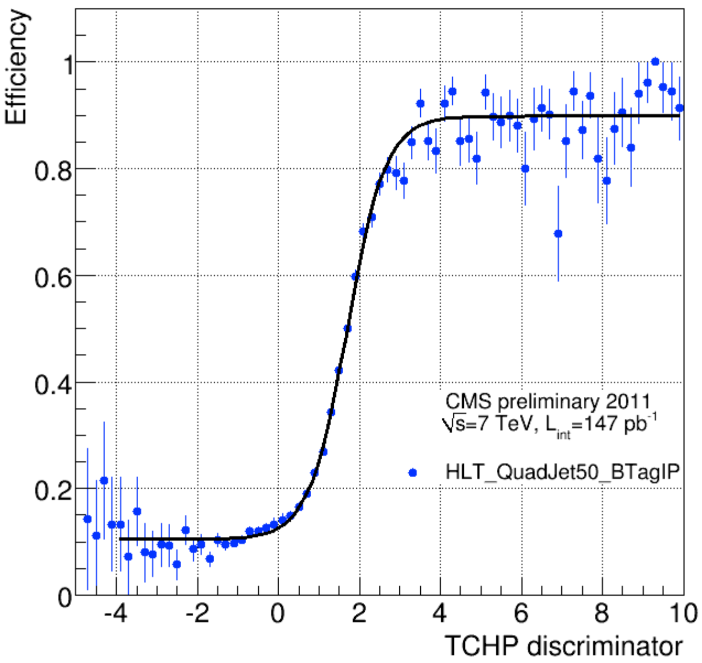
HLT_IsoMu24 trigger path efficiency
calculated with respect to
the offline reconstruction.

Jets



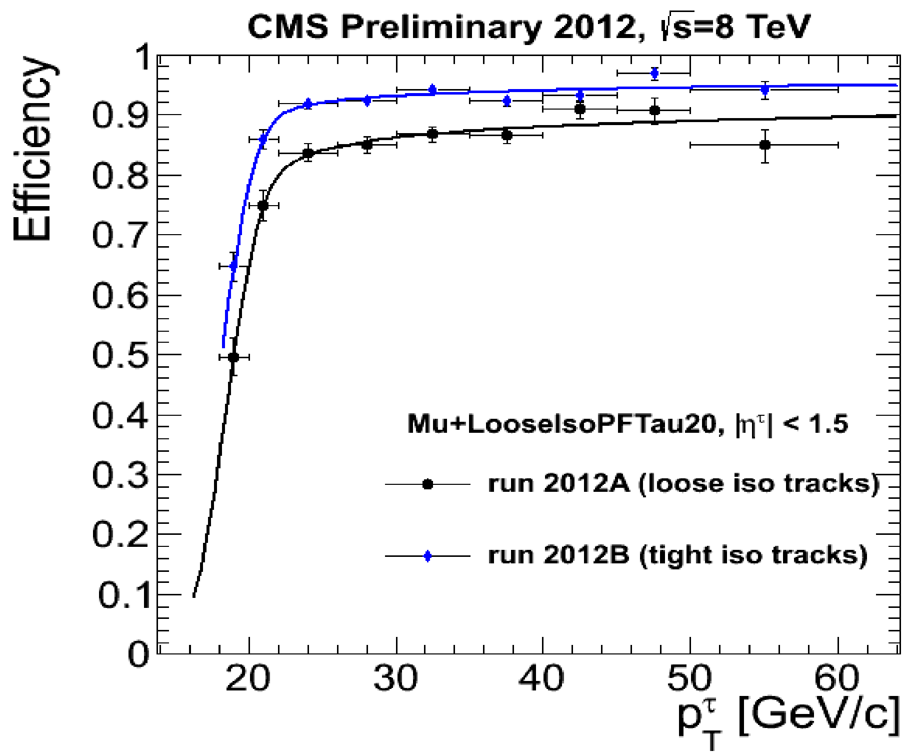
Turn-on cuve measured vs.
offline Particle Flow jet pT.
Trigger efficiency measured
on an unbiased
data sample from Run2012C.

b-tagging



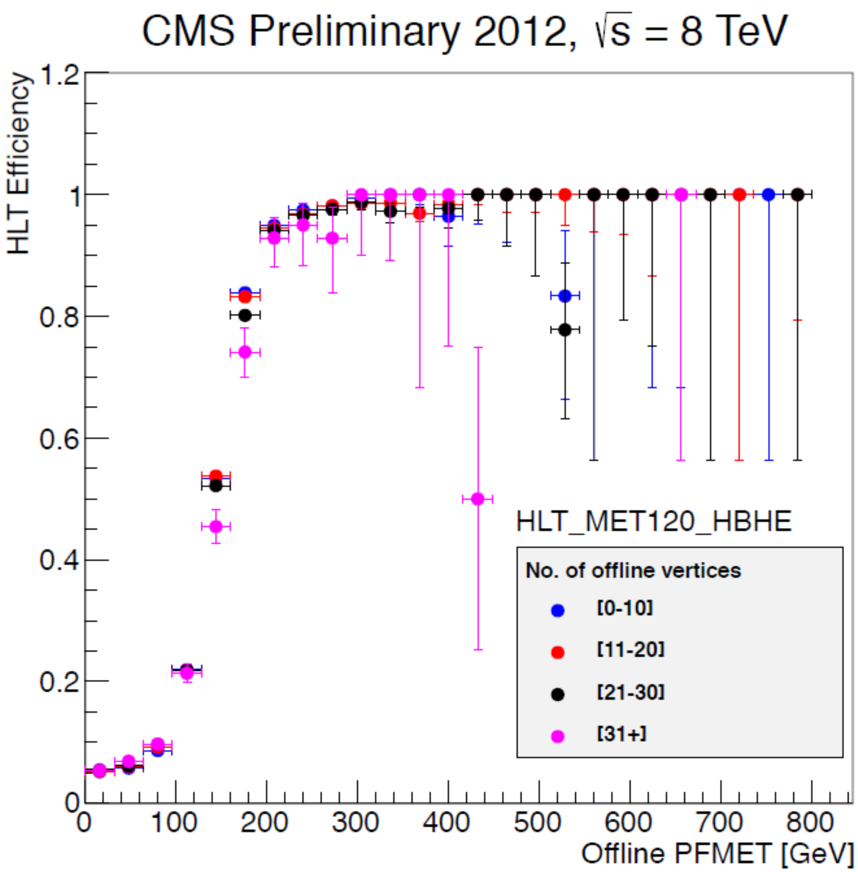
Turn-on curve of the Track Counting High Purity (TCHP) discriminator efficiency at HLT, with respect to the same variable computed offline.
The TCHP b-tagging discriminator is the third highest impact parameter significance for the tracks associated to a jet.
The online cut for this HLT path is TCHP > 2.

Isolated Particle Flow Tau



Efficiency measured using tag-and-probe technique with $Z \rightarrow \tau^+\tau^-$, $\tau \rightarrow \mu\ \nu$ + τ-hadr
using an unbiased dataset for the T&P.
- Difference in efficiency between run 2012A and 2012B: different quality criteria of isolation

MET



Turn-on curves for HLT_MET120_HBHE trigger,
in bins of different pileup
(based on # offline vertices):
PU has no effect on trigger turn-on.

Summary

- The CMS features a two-level trigger
- The High Level Trigger is a sequence of reconstruction and selection steps of increasing complexity
- HLT software is a dedicated version of the one used offline
- Reconstruction at HLT level shows **very good performance**
- More efforts are on-going in order to make the HLT performance more and more similar to the offline ones
- HLT is coping well with the increasing **pile-up**
- For the post-LS1 scenario, when an increase of a factor of 2.5 in rate is expected, new algorithms need to be developed

Spares

The HLT decision is taken as the logical “OR” of many independent trigger “paths”

- each path runs idependently from the others (in parallel)
- the CMS software framework guarantees that the same reconstruction block is not run twice

All trigger paths are alway run.
The HLT decision is used to split the events into streams (data, calibration, monitoring - online) and dataset (offline)

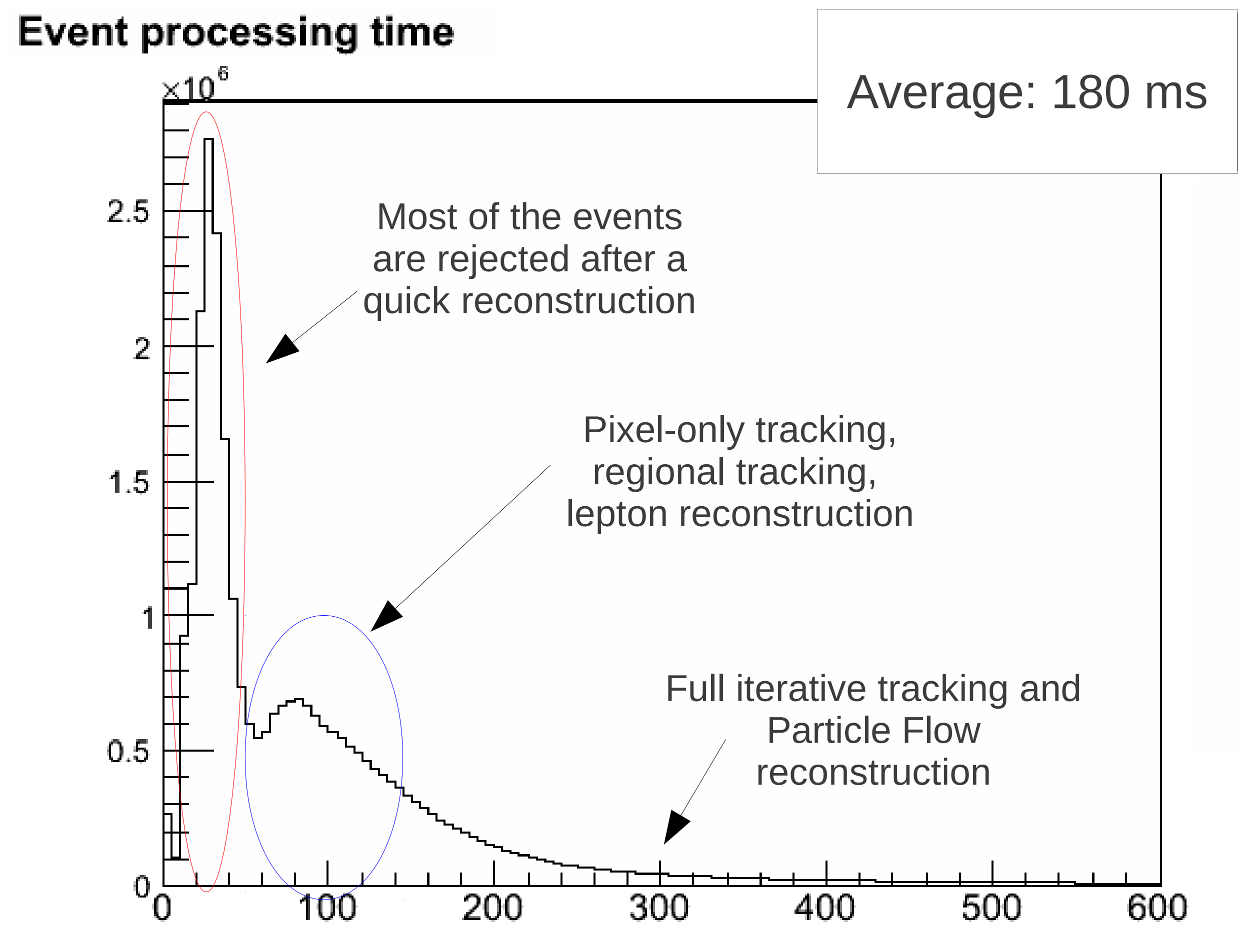
The current HLT menu has ~400 independent paths

All paths follow a similar structure:
- unpacking and accessing the basic information
- looking for a L1 seed
- reconstruction, seeded by the L1 object
- filtering
- further reconstruction
- further filtering

Except for the simplest paths, we need to reconstruct different object and physical quantities.

Strategy:
- start with regional, fast code
- try to apply the highest rejection as soon as possible
- leave slow or global reconstruction code last

The CPU time for a given HLT menu:
- is dominated by L1 rate
- increases with luminosity



Timing during a short run taken in November 2012 (average luminosity ~ $7{\cdot}10^{33}$ cm^{-2} s^{-1})