

μ GT : level-1 trigger menu

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Ingredients of level-1 trigger menu

- Objects in ± 2 BX

jet: $|\eta| \leq 5, E_T \leq 1023 \text{ GeV}$
 $(\Delta\eta, \Delta\phi, \Delta E_T) = (0.0435, 0.0436, 0.5)$

$e\gamma$: $|\eta| \leq 5, E_T \leq 255 \text{ GeV}$
 $(\Delta\eta, \Delta\phi, \Delta E_T) = (0.0435, 0.0436, 0.5)$

τ : $|\eta| \leq 5, E_T \leq 255 \text{ GeV}$
 $(\Delta\eta, \Delta\phi, \Delta E_T) = (0.0435, 0.0436, 0.5)$

μ : $|\eta| \leq 2.45, E_T \leq 255 \text{ GeV}$
 $(\Delta\eta, \Delta\phi, \Delta p_T) = (0.010875, 0.0109, 0.5)$

NB: numbers are from scales defined in interface note

Ingredients of level-1 trigger menu

- Energy sums in ± 2 BX
 - total- E_T/H_T : ≤ 2047 GeV, $\Delta E_T = 0.5$ GeV
 - missing- E_T/H_T : ≤ 2047 GeV, $(\Delta\phi, \Delta E_T) = (0.0436, 0.5)$
- External signals in ± 2 BX, e.g. BPTX
- Cuts on objects and energy sums
 - η range: up to 2 η ranges on each object
 - ϕ range: up to 2 ϕ ranges on each object + missing- E_T/H_T
 - isolation: 2-bits for $e\gamma, \tau, \mu$
 - quality: 4-bits for μ
 - charge: 1-bit for μ

Ingredients of level-1 trigger menu

- Functions
 - multi-objects:** di-objects, tri-objects, quad-objects triggers of the same type (jet, $e\gamma$, τ , μ)
 - distance:** $\Delta\eta$, $\Delta\phi$, ΔR between two objects.
 $\Delta\phi$ between object and energy sum
 - mass:** invariant mass between two objects
- Cuts on functions
 - charge correlation:** like-sign or opposite-sign for di-muon, tri-muon, quad-muon triggers
 - range:** $\Delta\eta$, $\Delta\phi$, ΔR ranges for distance.
mass range for invariant mass
- Logical operators: NOT, AND, OR, XOR

Example of algorithms

- Single object trigger

MU10	μ with $p_T \geq 10$ GeV
EG10+1	$e\gamma$ with $p_T \geq 10$ GeV at BX+1
EG10 [EG-ISO_0xE]	isolated $e\gamma$ with $p_T \geq 10$ GeV
TAU10 [TAU-ETA_CEN]	τ with $p_T \geq 10$ GeV in central η region
JET10 [JET-ETA_FWD_NEG, JET-ETA_FWD_POS]	jet with $p_T \geq 10$ GeV in forward η regions

- Multi-object trigger

comb{EG3p5, EG3p5}	di- $e\gamma$ with $p_T \geq 3.5$ GeV
comb{MU10, MU10, MU10}	tri- μ with $p_T \geq 10$ GeV

- Cross trigger

EG10 AND MU10	cross trigger of $e\gamma$ and μ
JET40 AND MU10	cross trigger of jet and μ

these expressions available from CMSSW_8 series
cut specified in [], e.g. TAU-ETA_CEN, to be defined separately

Example of algorithms

- Topological trigger

`dist{MU10,MU10} [DPHI_Hww_lvlv]`

di- μ with $\Delta\phi$ compatible with $H \rightarrow WW$

`dist{JET20,JET20} [DETA_VBF] VBF di-jet`

- Invariant-mass trigger

`mass{MU15,MU15} [MASS_Z] di- μ with invariant mass compatible with Z`

NB: being implemented in firmware with fixed point, will be available in emulator from CMSSW_8 series with floating point implementation

Level-1 menu grammar

Table: Components of the grammar.

Object	μ , $e\gamma$, jet, τ , E_T , H_T , $E_{T\text{miss}}$, $H_{T\text{miss}}$
Function	logical or mathematical computation based on objects
Cut	condition applied on objects or on the return value of a function
External signal	a pre-defined set of binary input signal to the μGT
Logical operators	AND, OR, XOR and NOT

Naming convention of object;

$\langle \text{type} \rangle [\langle \text{comparison operator} \rangle] \langle \text{threshold} \rangle [\langle \text{bunch crossing offset} \rangle]$.

type: MU, EG, TAU, JET, ETT, HTT, ETM and HTM.

comparison operator: .ge. or .eq. (default is .ge.)

threshold: numeric value in unit of GeV. decimal point is expressed as p.

bunch crossing offset: -2, -1, +0, +1 and +2. (default is +0)

For example, a muon object with $p_T \geq 20.5$ GeV at bunch crossing offset of 0 can be expressed as either MU.ge.20p5+0 or MU20p5.

Table: Classification of object.

particle	MU, EG, TAU, JET
scalar	ETT, HTT
vector	ETM, HTM

Table: A list of function.

comb	for double-, triple- and quad-objects trigger
dist	for correlation trigger
mass	for invariant mass trigger

Expression of function

$\text{func}\{\text{obj1}, \text{obj2}\} [\text{cut}]$

Table: A list of cut types.

Cut type	meaning
ETA	specifies range of η for object
PHI	specifies range of ϕ for object
QLTY	specifies quality of object
ISO	specifies isolation of object
CHG	specifies charge of object
DETA	specifies range of $\Delta\eta$ for two objects
DPHI	specifies range of $\Delta\phi$ for two objects
DR	specifies range of ΔR for two objects
MASS	specifies range of invariant mass of two objects
CHGCOR	specifies charge correlation of objects

Naming convention of a cut for object;

$\langle \text{target} \rangle - \langle \text{type} \rangle - \langle \text{user specified} \rangle .$

Naming convention of a cut for function;

$\langle \text{type} \rangle - \langle \text{user specified} \rangle .$

$\langle \text{target} \rangle$: one of object type, $\langle \text{type} \rangle$: cut type, $\langle \text{user specified} \rangle$: text string

Table: Possible combination of object and cut, function and cut.

MU	ETA, PHI, CHG, QLTY, ISO
EG, TAU	ETA, PHI, ISO
JET	ETA, PHI
vector object	PHI
distance function	DETA, DPHI, DR
invariant mass function	MASS
multi-object function	CHGCOR for MU

Level-1 menu grammar

A set of pre-defined external signals will be provided.

Naming convention of external signal;

EXT_ < predefined signal name > [< bunch crossing offset >].

bunch crossing offset: -2, -1, +0, +1 and +2. (default is +0)

Level-1 menu grammar

Example menu:

https://svnweb.cern.ch/trac/cactus/browser/trunk/cactusprojects/ugt/menu/2015/L1Menu_CollisionsHeavyIons2015_v4_uGT_v2/xml/L1Menu_Co