Stage-2 Tau Algorithm: firmware-oriented pseudocode

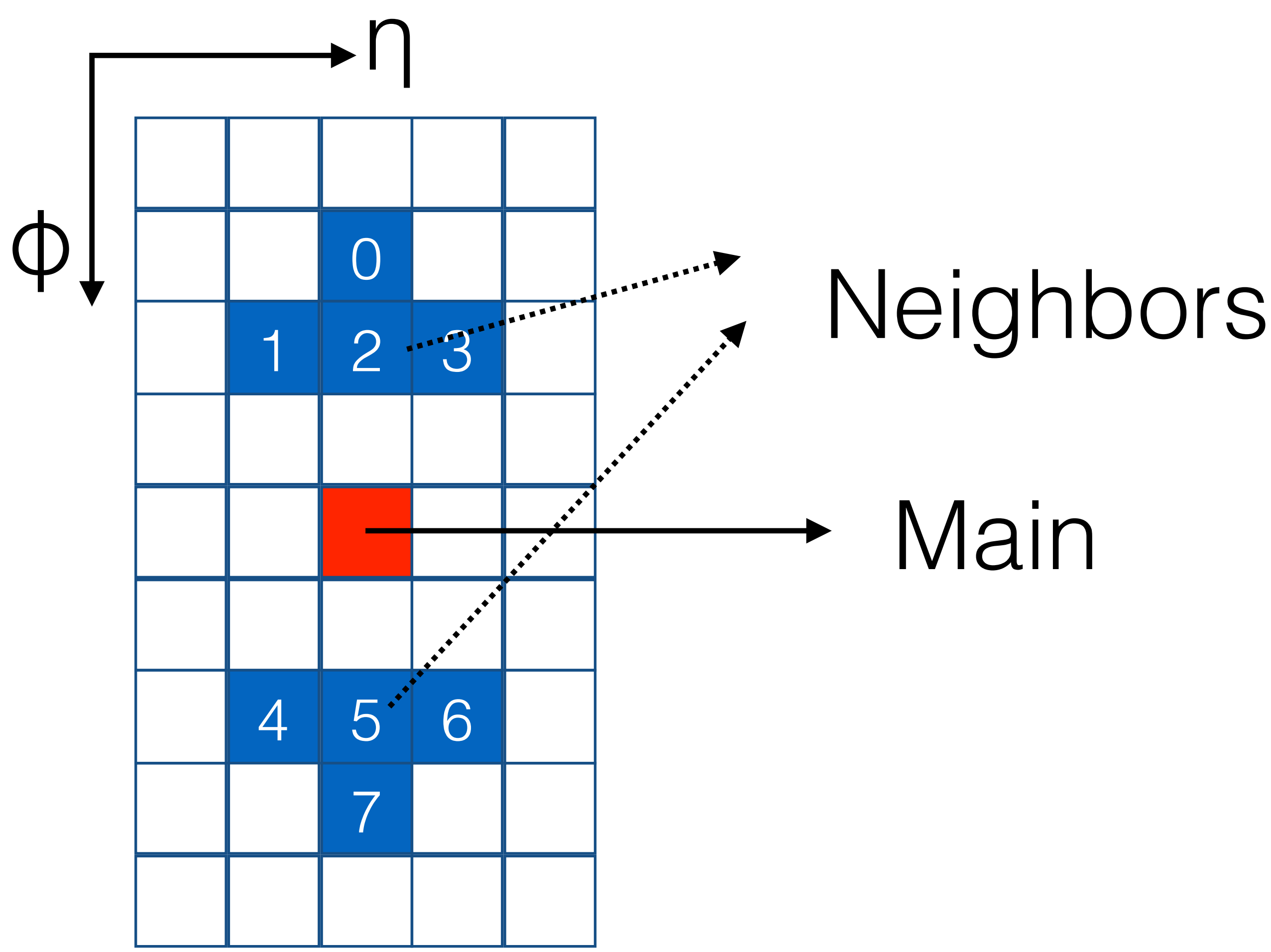
Luca Cadamuro

Laboratoire Leprince-Ringuet (École polytechnique)

Algorithm main steps

- Merging strategy → L1 tau candidate creation
  - 1: Neighbor search
  - 2: Merging
- 3: Calibration
- 4: Isolation
- 5: Shape veto

Introduction – 1



FLAGS DIFFERING FROM EG ALGO:

+ isTauSeed = 1 [DEFAULT]
- H/E
- FG bit

isTau seed is true if the corresponding cluster is the center of a tau L1 candidate (both merged and non merged)

- Squares indicate **clusters** (i.e., size can be larger than 1 TT)
  - the square indicates the cluster position, i.e. the cluster seed TT
- We work on formed clusters
- Neighbors clusters are searched only in the highlighted pattern

Introduction – 2

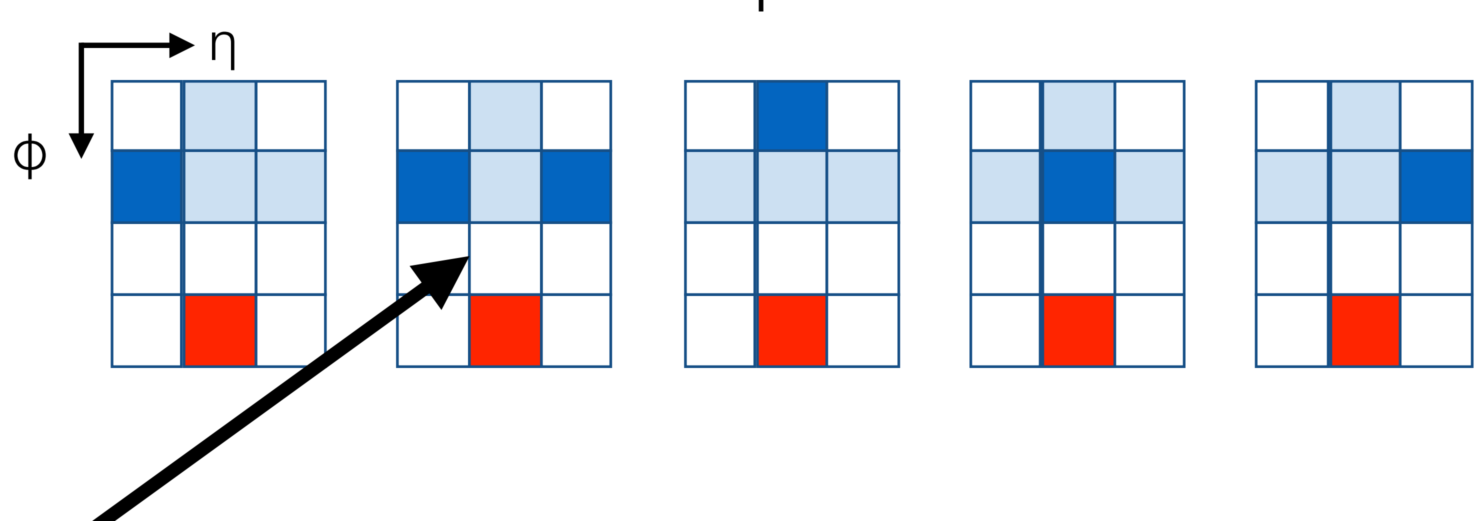
A. Need to find:
   1. if at least 1 neighbor exist
   2. if existing , the neighbor with the highest energy

B. **IF** neighbor exist:
   1. decide if it is main (if not, isTauSeed = false)
   2. add main and neighbor energies if isTauSeed == true

C. **ELSE**
   1. it will be a non-merged L1 tau candidate

This search can start earlier than energy comparison as cluster energy is computed in the last step of clustering algo
→ this information is available at an earlier stage

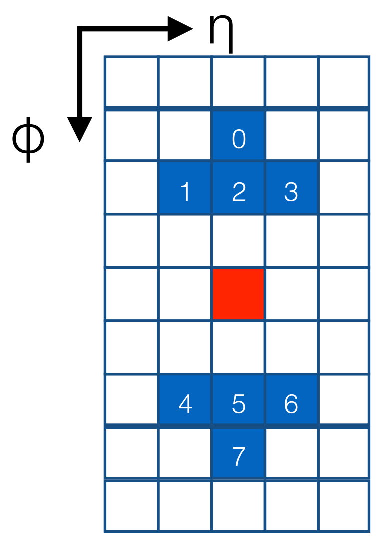
NOTE: there are limited possibilities for the number of valid neighbors

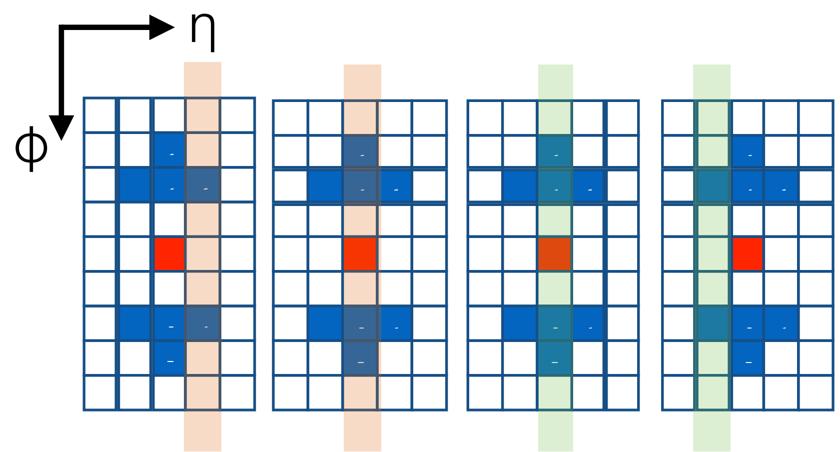


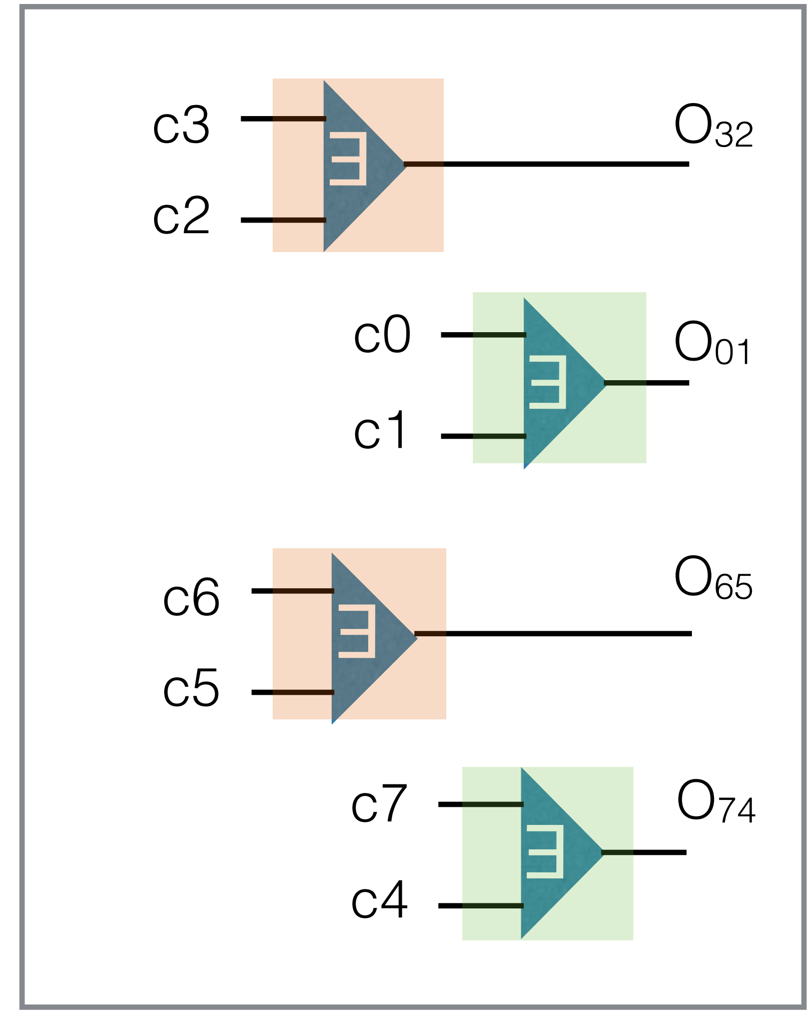
+ symmetrical in phi

Only this will need more than one comparison on the same phi side

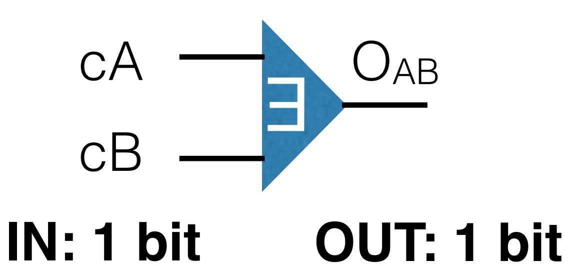
I. Neighbor search – strategy 1







- Input comes from **ClusterQuality** (after Filtering)
- **cX** means the value of Cluster.center (i.e. the flag that states if a cluster exists or not at a certain position)
- Output bit is denoted as O_{AB}

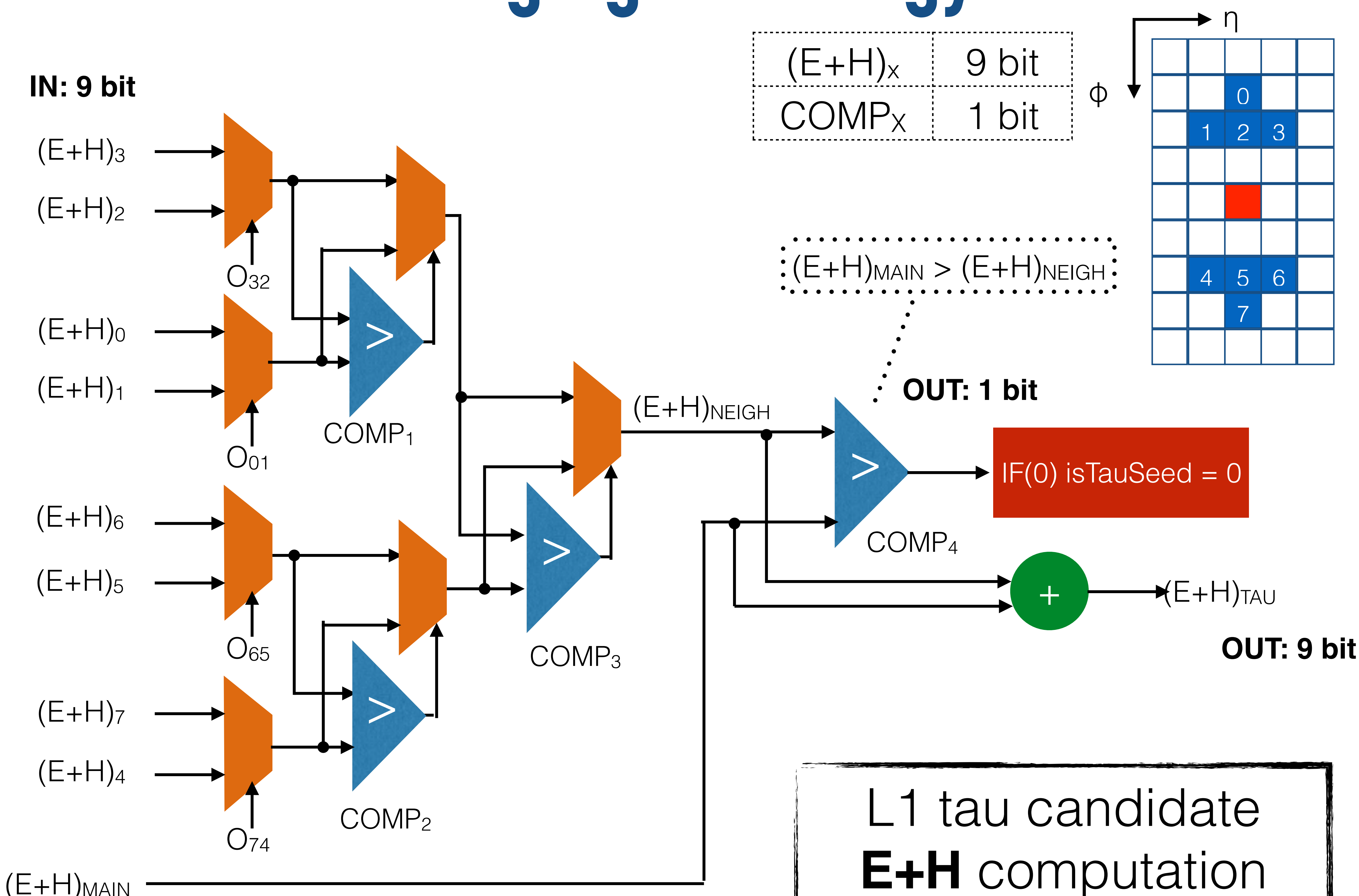


cA	cB	O_{AB}
1	0	0
0	1	1
0	0	0
1	1	NEVER

out: 0 ⇢ cA
out: 1 ⇢ cB
if both are zero, force to 0 as default

II. Merging – strategy 1

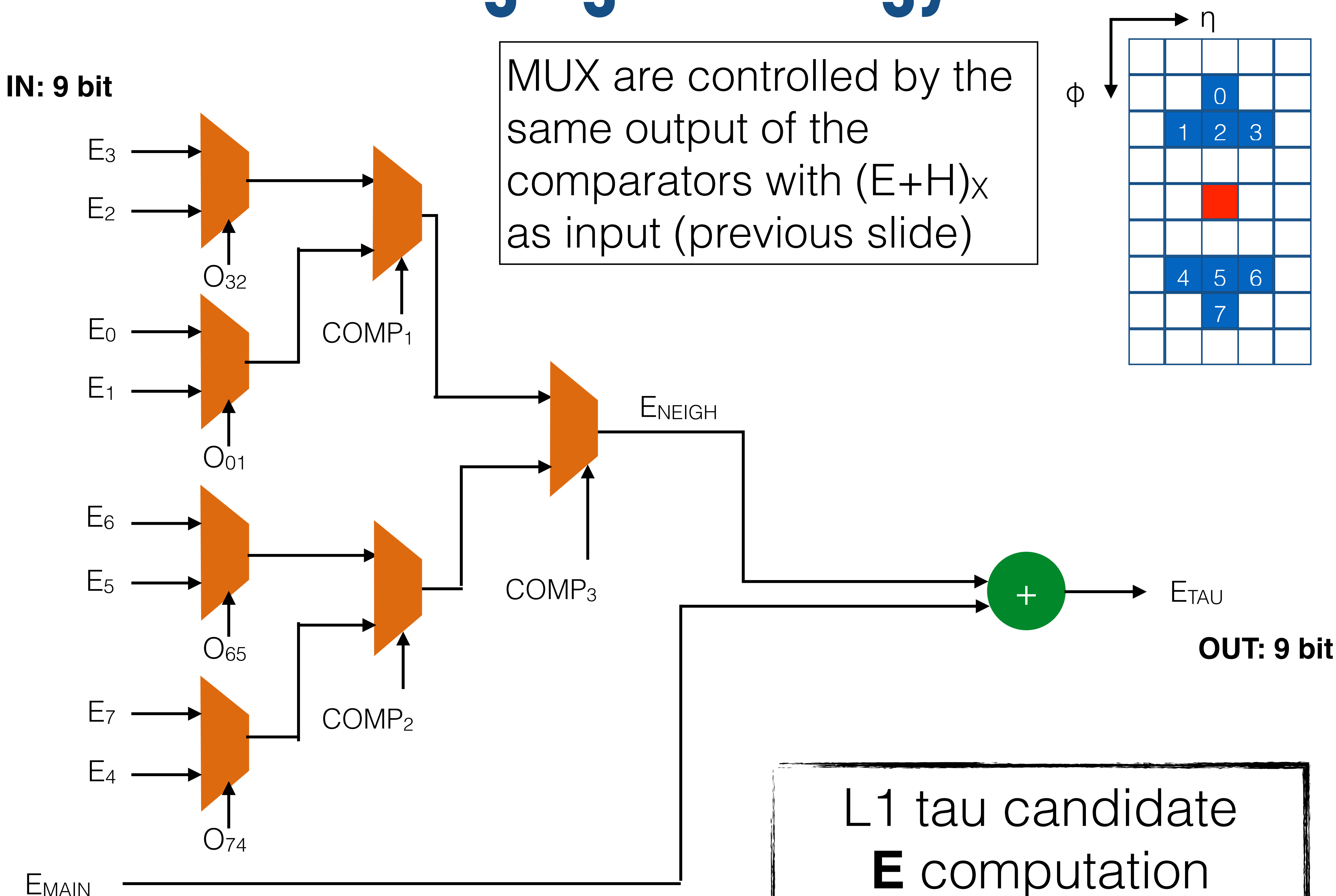
$(E+H)_X$	9 bit
$COMP_X$	1 bit



L1 tau candidate
E+H computation

II. Merging – strategy 1

MUX are controlled by the same output of the comparators with $(E+H)_X$ as input (previous slide)



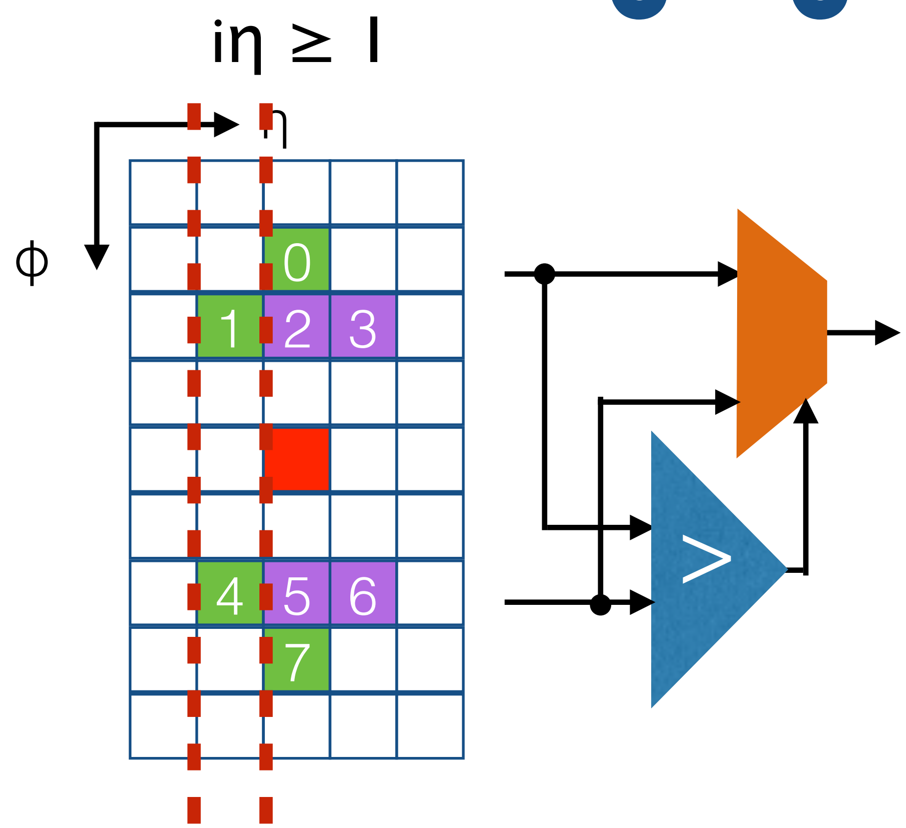
L1 tau candidate
E computation

II. Merging [comments]

Symbols used in the previous slide and comments:

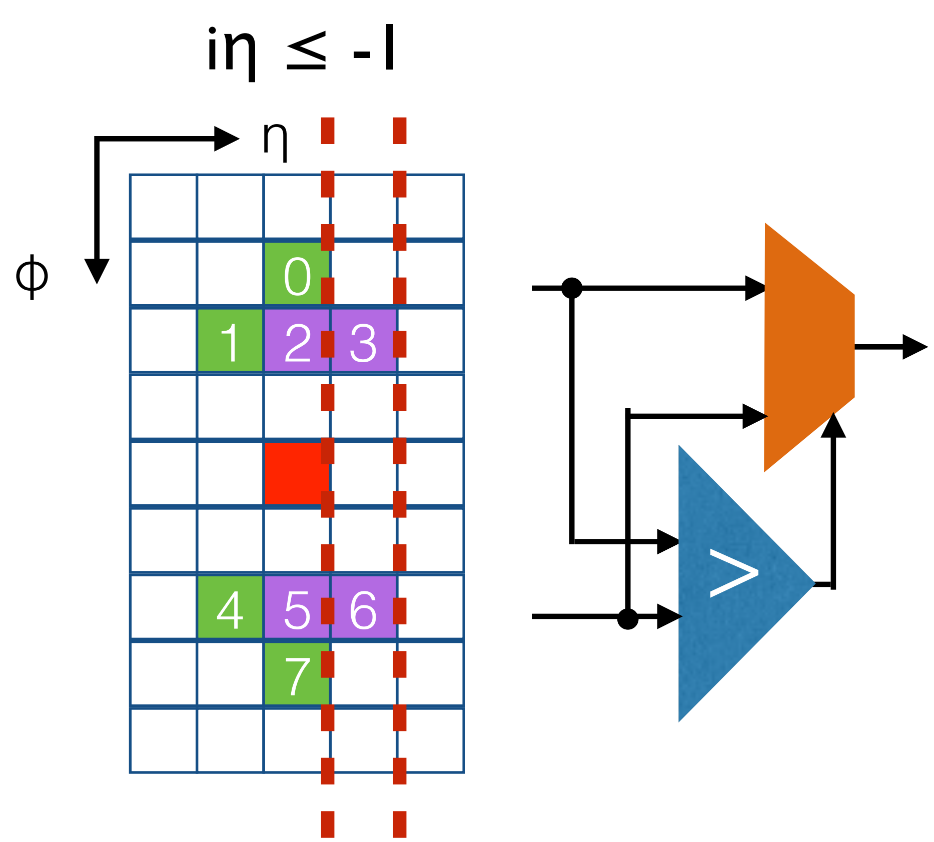
- **$(E+H)_X$** denotes the full tau cluster energy resulting from **Tau_ClusterTriggerFormer**
- **O_{XY}** denotes the mux output from neighbor search phase
- **NOTE**: if a cluster does not exist ("center" is zero) $(E+H)_X$ and E_X **must be 0** so that the mux selects this value
- Each comparator consists in some ">" and ">=" operation according to the position as in the EG algo (see next slide)
- The current cluster (i.e. the one centered in the computing unit in use) is denoted as "MAIN"
- If no neighbor exists, everything is fine because E_{NEIGH} is 0 and therefore
  - will fail the energy comparison
  - nothing is added to E_{MAIN}

II. Merging [comparator structure – 1]



mux is commanded by the discriminator so that quantities (E, E+H) related to the first input [on the left of the operator in the table] pass if condition is true, else those related to the second input [on the right in the table] pass

iη ≥ I			
$COMP_1$	$(E+H)_{23}$	>	$(E+H)_{01}$
$COMP_2$	$(E+H)_{56}$	>	$(E+H)_{47}$
$COMP_3$	$(E+H)_{0123}$	>	$(E+H)_{4567}$

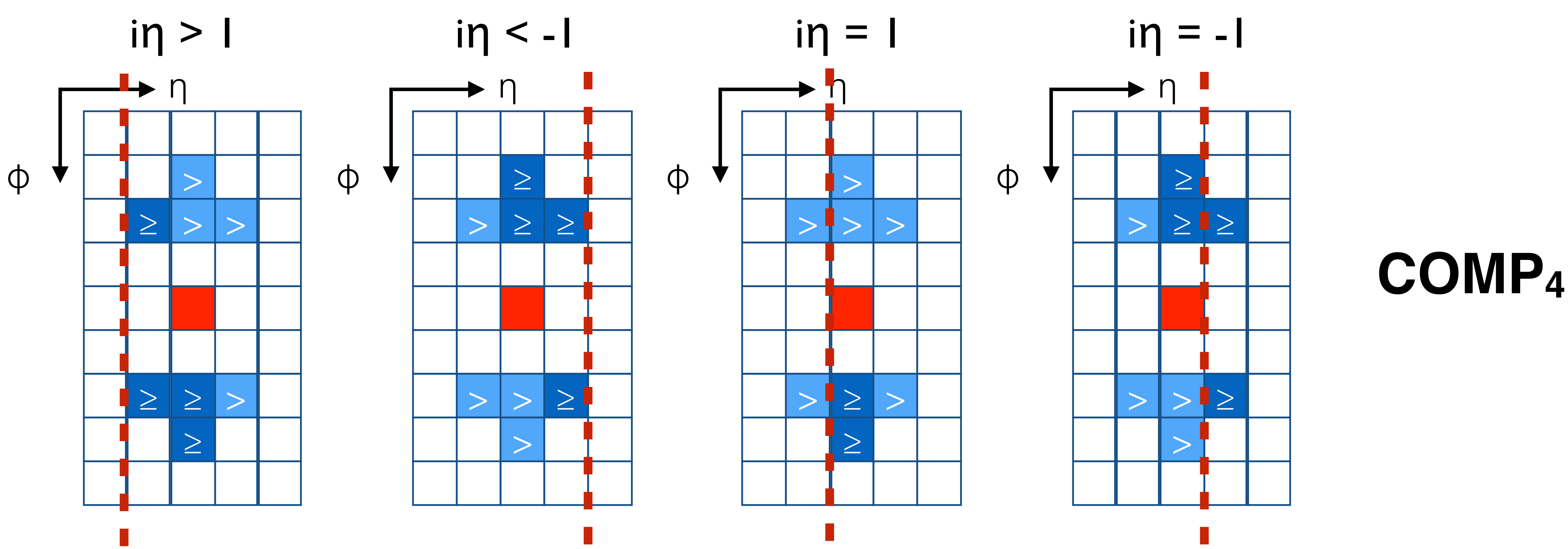


See slide 4: the only comparison on two existing clusters is 1-3, 4-6, so the most central position is favored.
Phi values choice is arbitrary

iη ≤ -I			
$COMP_1$	$(E+H)_{23}$	≥	$(E+H)_{01}$
$COMP_2$	$(E+H)_{56}$	≥	$(E+H)_{47}$
$COMP_3$	$(E+H)_{0123}$	≥	$(E+H)_{4567}$

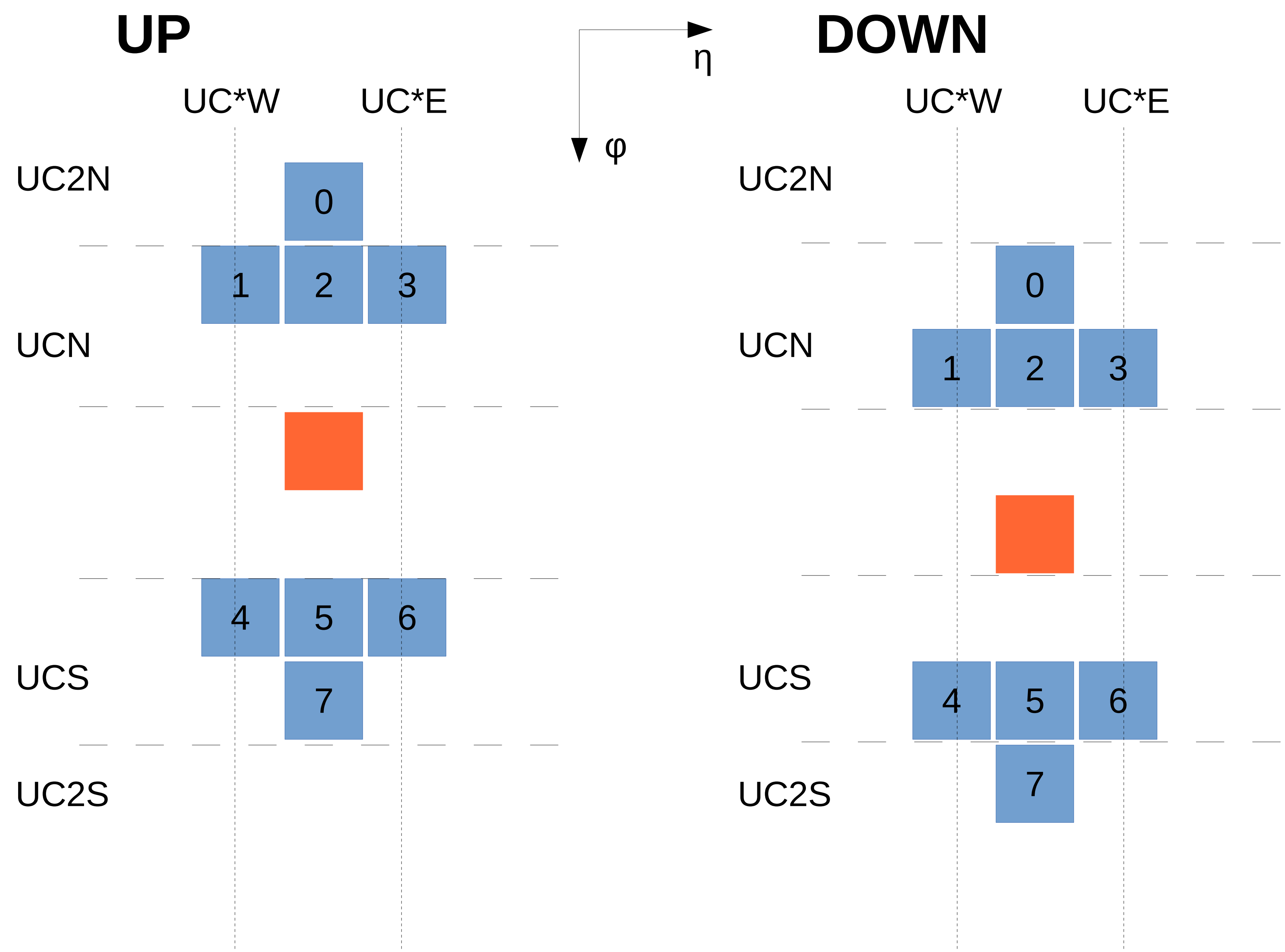
II. Merging [comparator structure – 2]

For $COMP_4$ (MAIN vs NEIGH comparison) the same logic used in the EG algo is applied



Merging – strategy 2

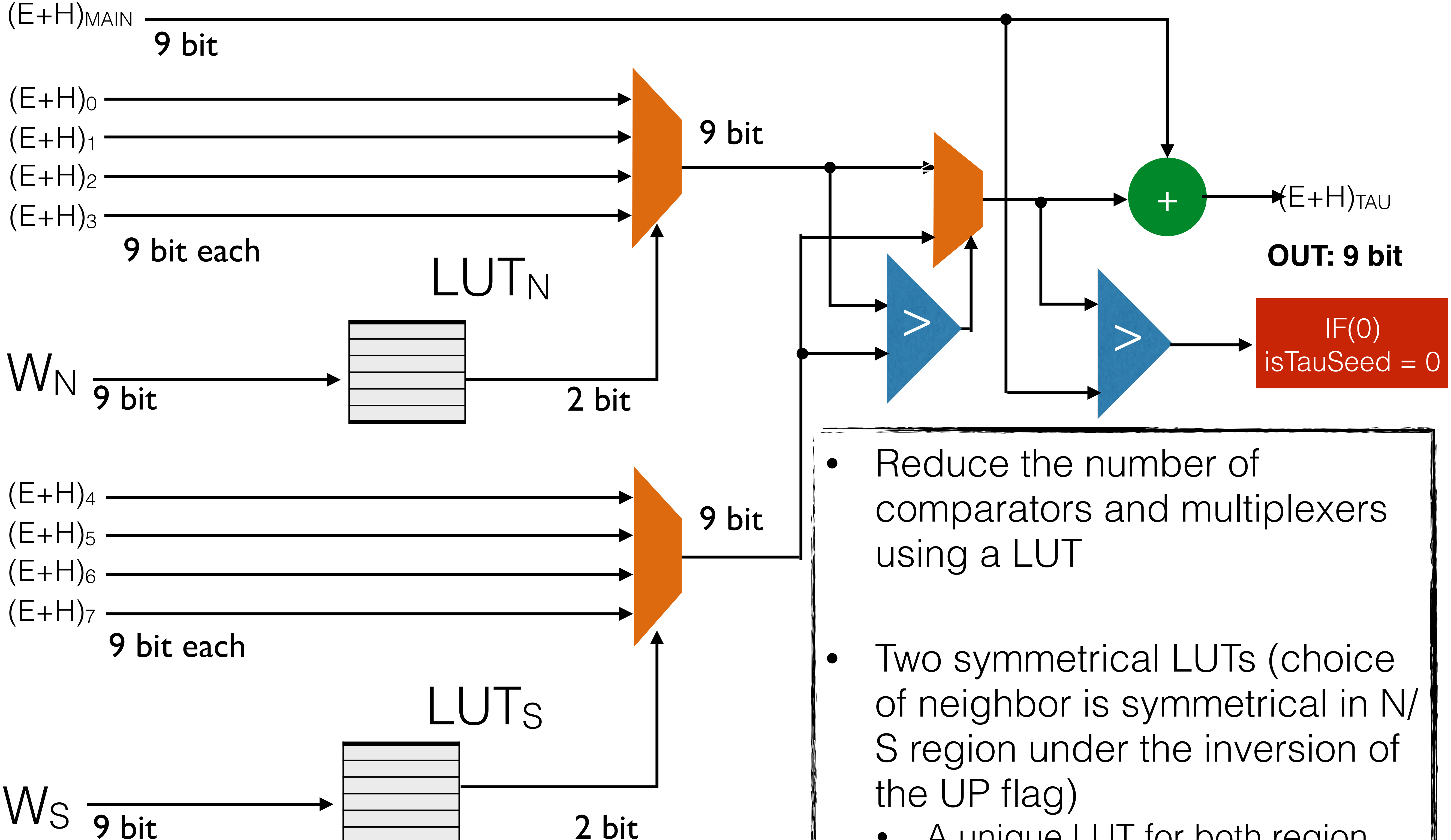
- Reduce the number of comparators and multiplexers using a LUT
- Form 2 words of 9 bits each (N and S part separate)



$$W_N = C_{2N}\ C_{NW}\ C_N\ C_{NE}\ UP_{2N}\ UP_{NW}\ UP_N\ UP_{NE}\ UP_{MAIN}$$

$$W_S = C_{2S}\ C_{SW}\ C_S\ C_{SE}\ UP_{2S}\ UP_{SW}\ UP_S\ UP_{SE}\ UP_{MAIN}$$

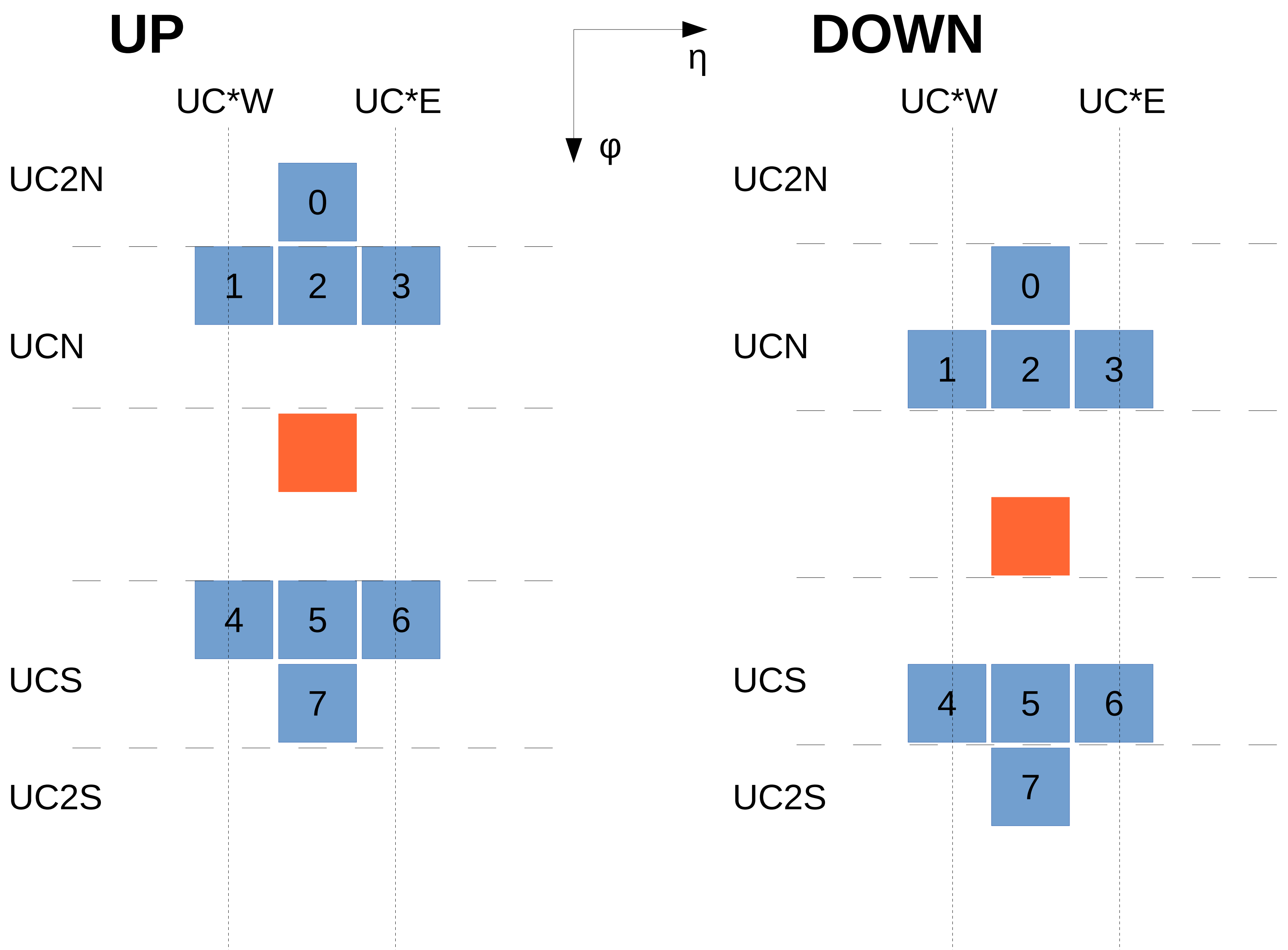
Merging – strategy 2



- Reduce the number of comparators and multiplexers using a LUT
- Two symmetrical LUTs (choice of neighbor is symmetrical in N/S region under the inversion of the UP flag)
    - A unique LUT for both region can be used to save space

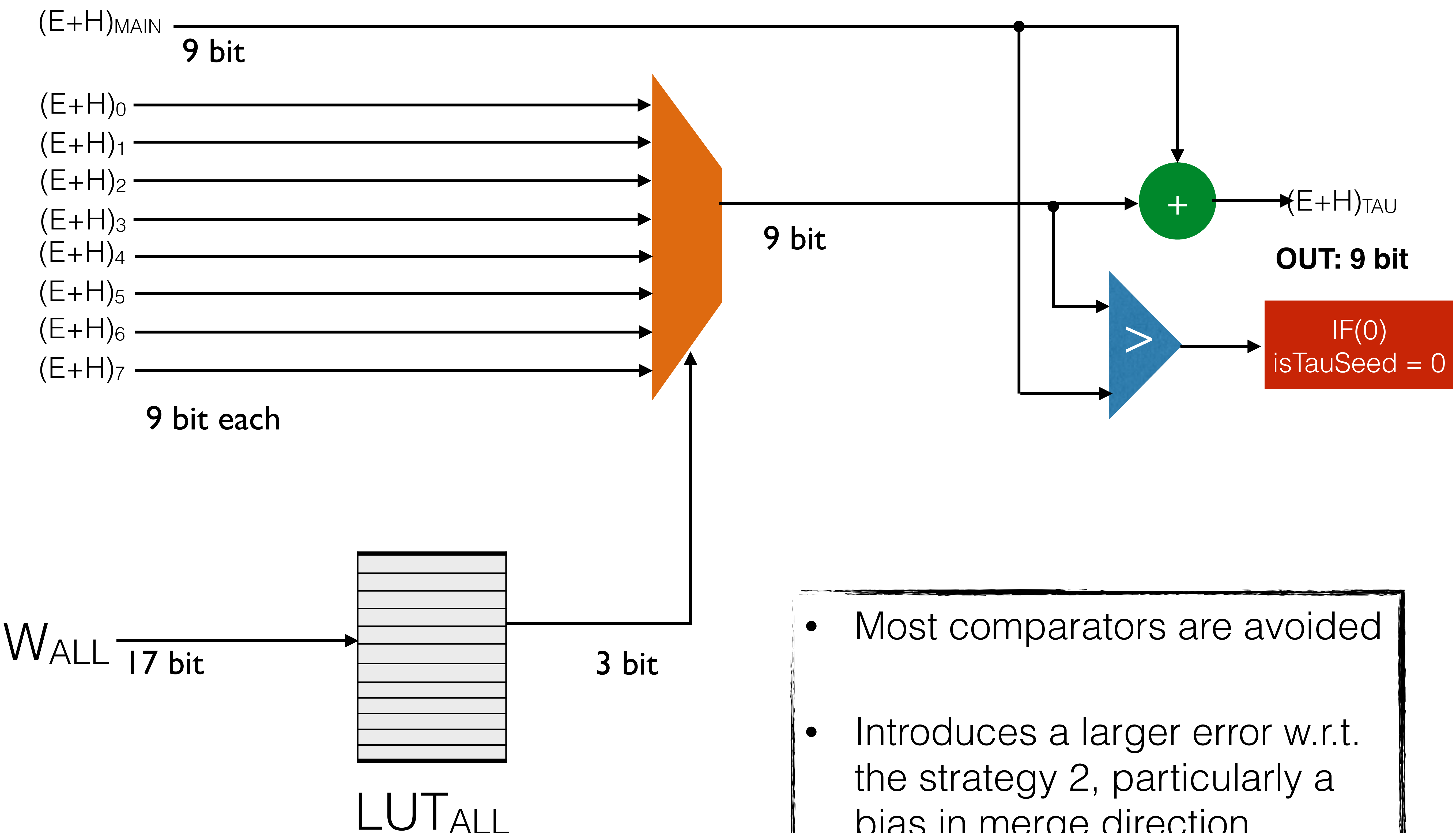
Merging – strategy 3

- Reduce the number of comparators and multiplexers using a LUT
- Form **1 words** of 17 bits (N and S parts **together**)



$W_{ALL} = C_{2N}\ C_{NW}\ C_{N}\ C_{NE}\ UP_{2N}\ UP_{NW}\ UP_{N}\ UP_{NE}\ C_{2S}\ C_{SW}\ C_{S}\ C_{SE}\ UP_{2S}\ UP_{SW}\ UP_{S}\ UP_{SE}\ UP_{MAIN}$

Merging – strategy 3



- Most comparators are avoided
- Introduces a larger error w.r.t. the strategy 2, particularly a bias in merge direction

III. Energy calibration

Calibration is computed as a linear function of the hadronic and EM energy deposited (energy of the full cluster)

- a module to compute E, H (had and EM energy) of the cluster is needed

$$E_{calib} = (aE_{EM} + bE_{had} + p) \cdot d(i\eta) \qquad \text{(if } E_{EM} > 0\text{)}$$

$$E_{calib} = (cE_{had} + q) \cdot d(i\eta) \qquad \text{(if } E_{EM} = 0\text{)}$$

- **a, b, c** depend on $E_{uncal} = E_{EM} + E_{had}$ and on the barrel/endcap cluster position
- **p, q** depend on the barrel/endcap cluster position
- **d** depends on the position of the cluster in iη units

Coefficient values are stored in a LUT.

In the case of merging, input E_{uncal}, E_{EM}, E_{had} are all computed as the sum of the energies of the two merged clusters.

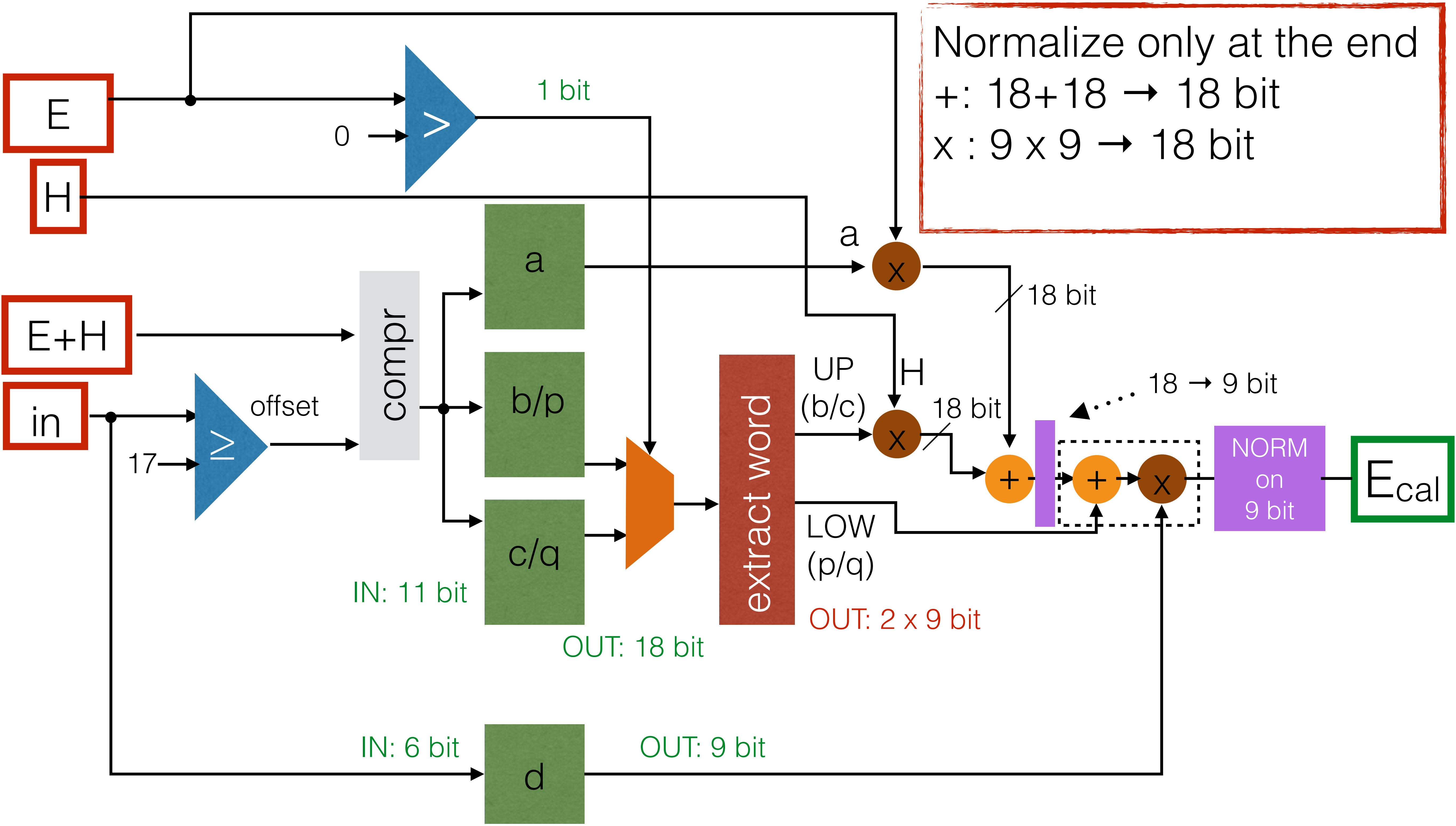
III. Energy calibration

- Input is E, H, E+H of the full tau cluster

- In Tau_ClusterTriggerFormer, need to compute E+H and E over the full cluster
  - H is retrieved as (E+H) - E

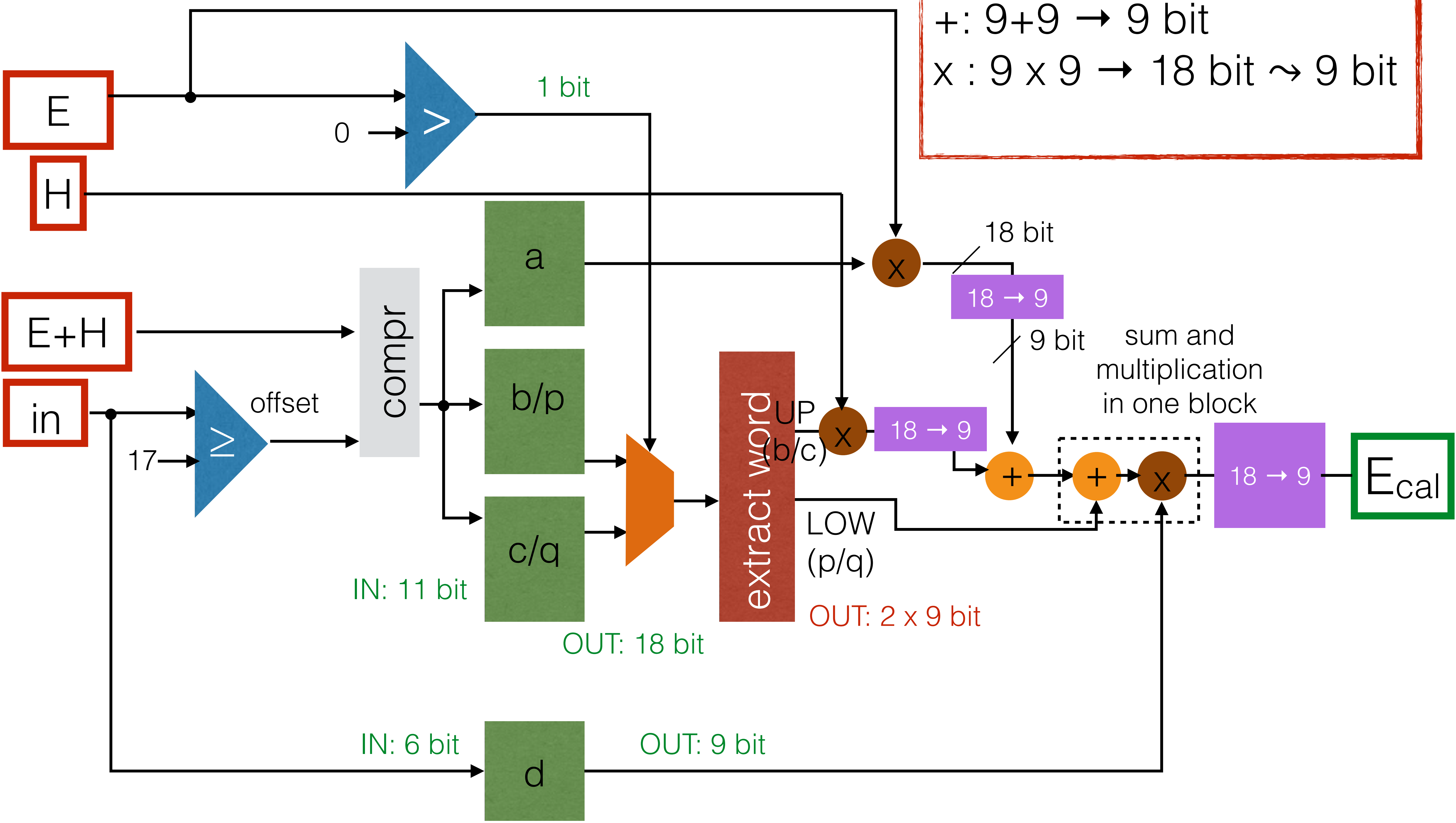
III. Energy calibration - data flow - str. 1

Normalize only at the end
+: 18+18 → 18 bit
x : 9 x 9 → 18 bit



III. Energy calibration – data flow – str. 2

Normalize always:
+: 9+9 → 9 bit
x : 9 x 9 → 18 bit ~> 9 bit



III. Calibration coefficients LUT

- Must contain 3 coefficients
  - A, B, and C

- Either B or C is used for calibration of a cluster; choice is done depending if E_{EM} is zero or not

- Two possibilities to encode the coefficients:
  1. One word with [A, B, C]; extract either B or C depending on the value of E_{EM}
     - This is the best approach for resources usage if enough bits are available for the LUT output
  2. Code A and [B, C] in two different LUT. Extract B or C according to an offset given by E_{EM}
     - In this way also the constants P and Q could be stored in the same word as B or C

IV. Isolation

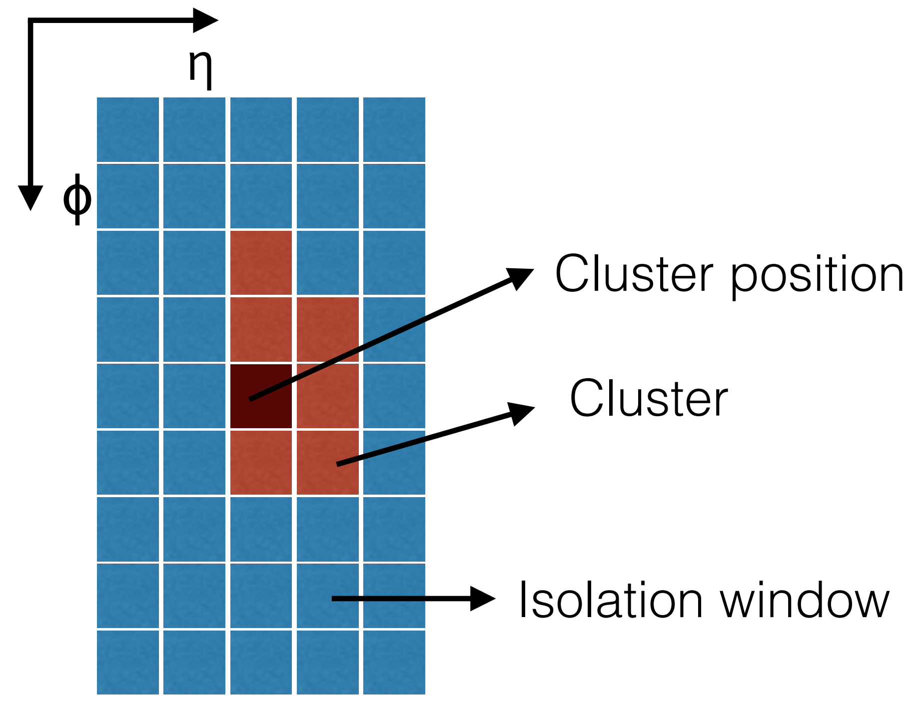
- Isolation is computed as:

$$E_{5x9} - E_{uncal} \leq IsoThr(E_{uncal}, N_{TT}, \eta)$$

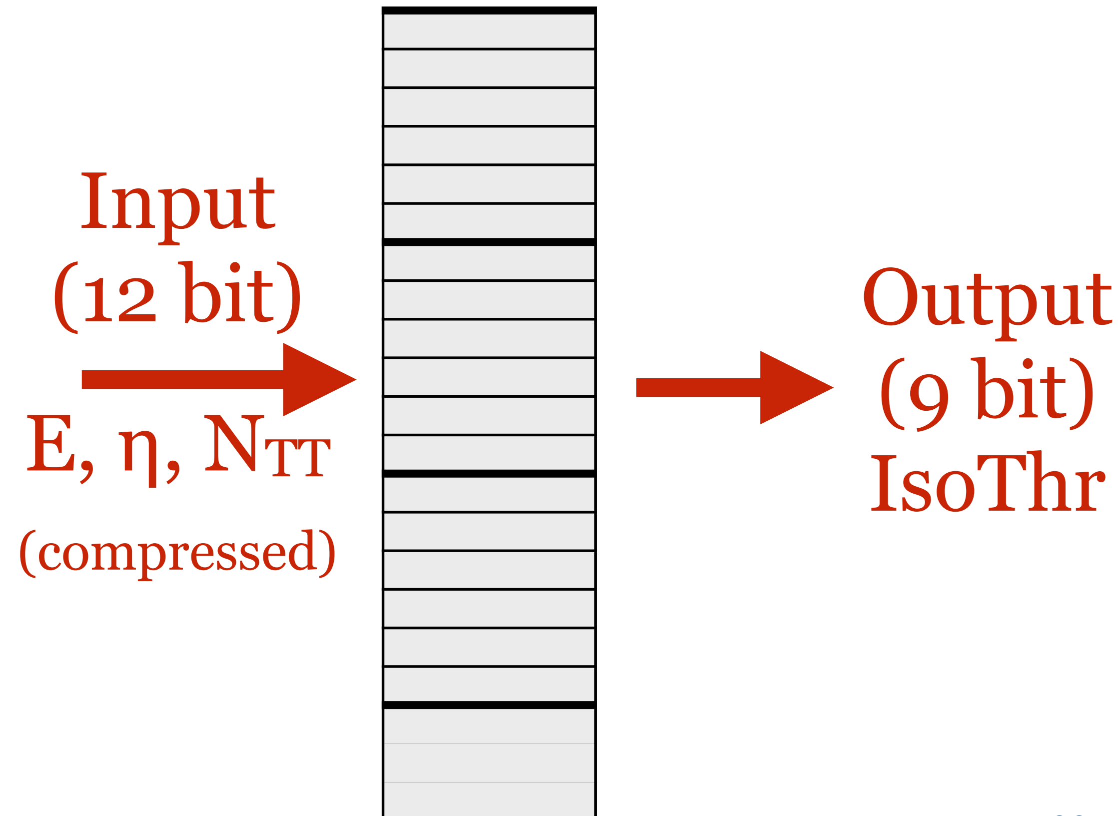
The threshold depends on the cluster energy and η as well as from the pile-up indicator N_{TT}.

Coded in a LUT. It could be also possible to input just (E, η) in two LUTs to get A, B coefficients to multiply externally by N_{TT} (IsoThr is a linear function of N_{TT}: IsoThr = A + B N_{TT})

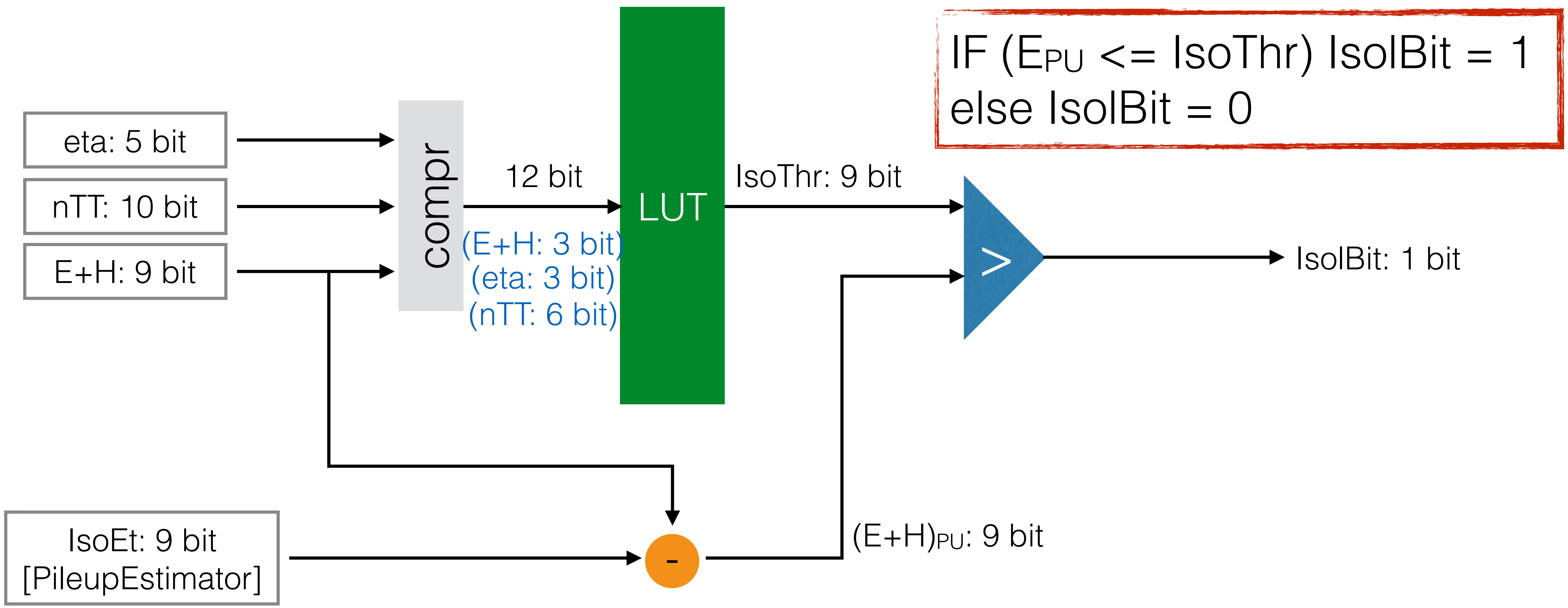
N_{TT} = num. of towers with E > 0 in the region iη ∈ [-4, +4]



- The isolation window has a size 5x9 in (η,ϕ) and is **always** centered around the cluster position (computed as the initial cluster seed position)
- Compression has already been developed and tested



IV. Isolation: data flow



V. Shape veto

- Cluster shape is coded in the same way as EG algorithm
- For merged clusters, only the main cluster shape is used at the moment
- Vetoed shapes encoded in a LUT
    - a fixed set of shapes is used at the moment
    - maybe can be optimized as a function of eta (+ other variables?)
- Shape veto is applied at the very end of the tau algorithm (after isolation)
    - we can gain some resources by putting it before isolation computation?