ATLAS LAr Calorimeter Commissioning for LHC Run-3

Energy computation in LATOME boards

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on behalf of the ATLAS LAr Calorimeter Group

XXVIII International Workshop on Deep-Inelastic Scattering and Related Subjects
Virtual Event @ Stony Brook University
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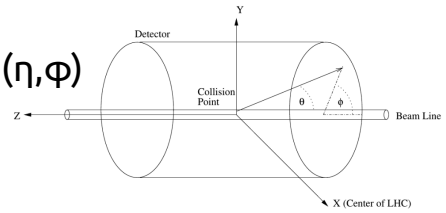
LAr Phase 1 upgrade : improving the trigger

ATLAS Calorimeter

Divided in subsystems based on Tiles and **Liquid Argon** (LAr)

➔ Each LAr subsystem divided in cells computing energy in (η,Φ) coordinates and 3-4 layers in depth



Hardware trigger system (L1 accept)

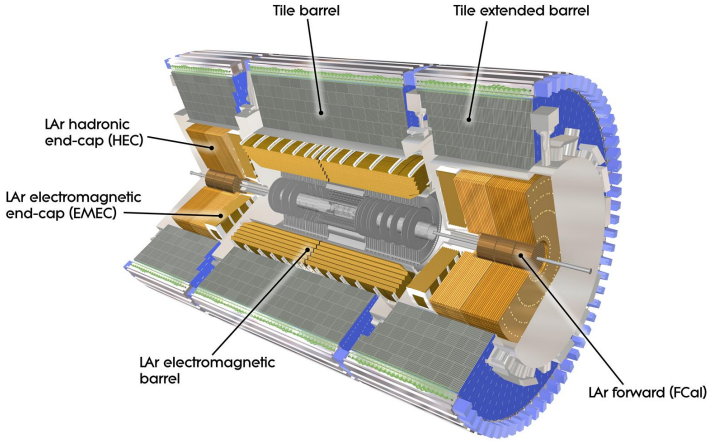
40 MHz→100 kHz = decide in few µs based on computed energy

➔ Reduced granularity to be faster : **Trigger Towers** ~ **60 cells** combined in depth and η,φ *(Δη x Δφ = 0.1 x 0.1)*

Phase 1 Upgrade

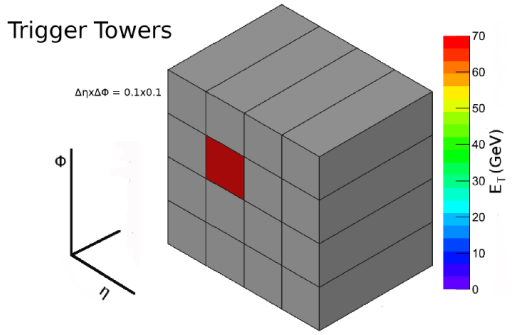
Higher pile-up expected : <µ> = **80** (Run 3) to **200** (HL-LHC)

➔ Increase granularity to improve discriminating power : **Super Cells**

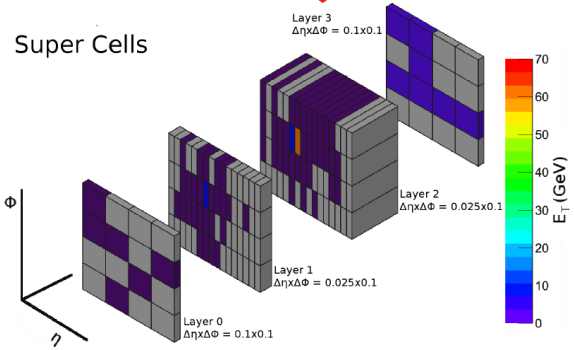


From Trigger Tower to SuperCells

- Granularity : 1 TT = 10 SC = 1+4+4+1 SC
  - ➔ From **5248 TT** to **34 048 SC**
- Digitization (improved precision)
- Pile-up subtraction (baseline correction) maintained though more challenging

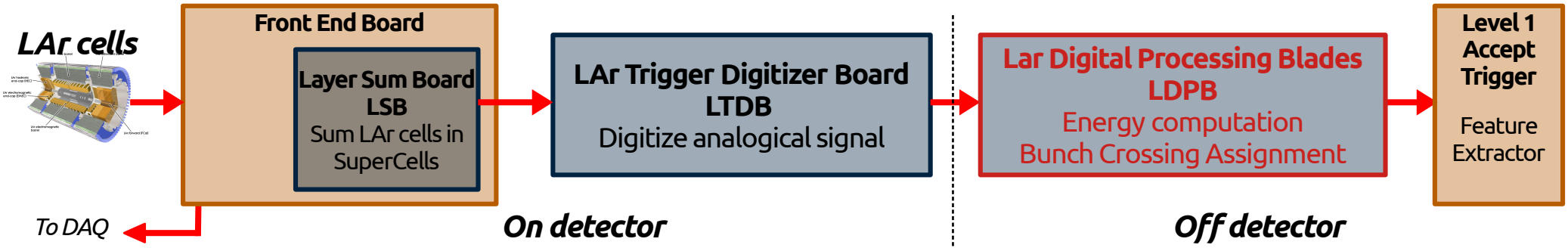


*Electron shower (E_T=70GeV) in **LAr Trigger Tower***



*Electron shower (E_T=70GeV) in **LAr SuperCells***

From LAr pulse to Energy



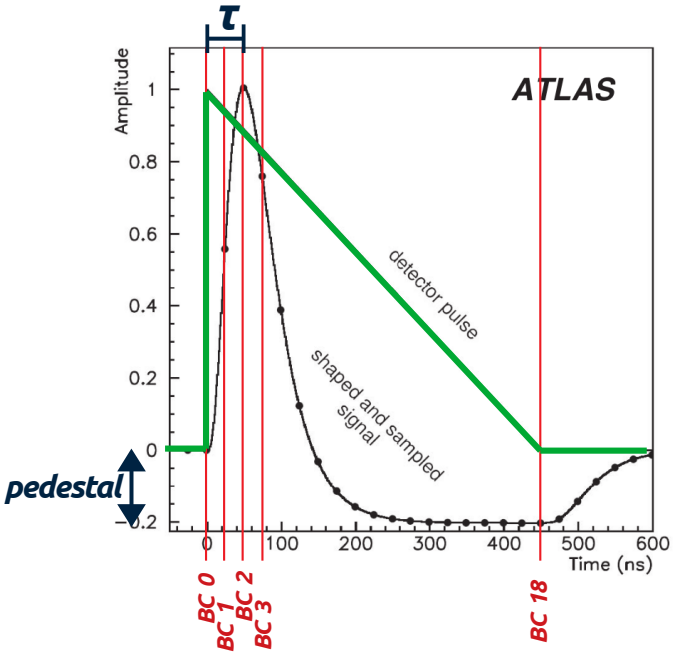
Detector pulse lasts around 400 ns, that is **around 20 bunch crossings** !

- Shaping of detector response : cancel out this **out-of-time pile-up**
  ➔ Negative part : need for a pedestal
- Digitization : at 40 MHz (bunch crossing frequency), **encoded on 12 bits**

Input data in LDPB : One ADC count (12 bit integer) per bunch crossing

- **Compute energy ? Associate to correct bunch crossing ?**
  ➔ **Optimal Filtering Coefficients (OFC)**

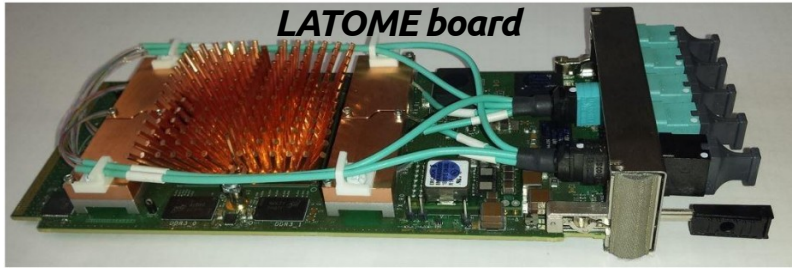
$$E_T(m) = \sum_{i=0}^{N-1} a_i \cdot (ADC_{m+i} - ped_{m+i}) \qquad \xi(m) = \tau(m) \cdot E_T(m) = \sum_{i=0}^{N-1} b_i \cdot (ADC_{m+i} - ped_{m+i})$$

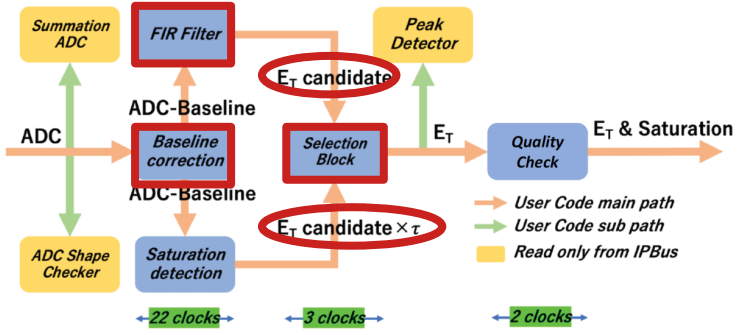


Energy computation in LATOME

Energy computation, done in **UserCode of LATOME** board (FPGA) in **L**Ar **D**igital **P**rocessing **B**lades, need coefficients :

- ➔ **SuperCell Specific** : to be stored in **correct register** of correct LATOME
- ➔ From calibration run = **condition specific** *(run number, lumi block,...)* : stored in **Condition database** (~ database with Intervals of Validity)



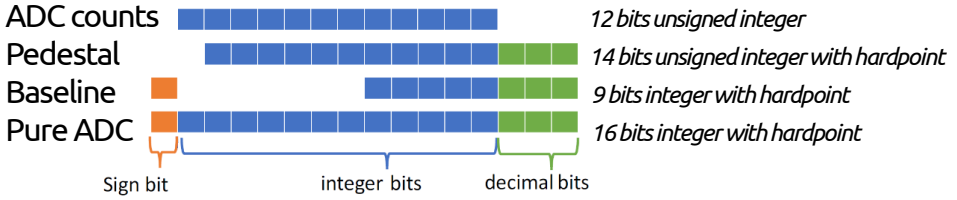


OFCs, pedestals come from **calibration** runs as **floats**

- – Multiplied by factors to make least significant bit of computation (DSP) output correspond to 12.5 MeV
- – Converted to 13bit + 1 sign bit **integers** to be stored in registers

➔ **Correctly implemented in LATOME ? Computation result comparable to full float precision ?**

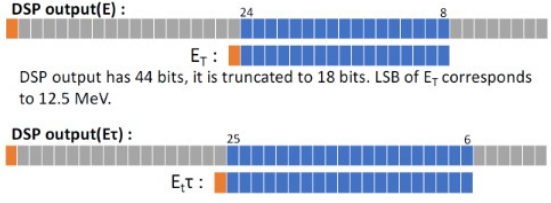
ADC input to Filtering block



FIR Filter

$$E_T(m) = \sum_{i=0}^{N-1} a_i \cdot (ADC_{m+i} - ped_{m+i})$$

$$\xi(m) = \tau(m) \cdot E_T(m) = \sum_{i=0}^{N-1} b_i \cdot (ADC_{m+i} - ped_{m+i})$$



Selection Block

$$\begin{cases} -8E_T(m) < \xi\,(m) < 16E_T(m) \;\text{ for }\; 10\ \text{GeV} < E_T(m) \\ -8E_T(m) < \xi\,(m) < 8E_T(m) \;\text{ for }\; 0 < E_T(m) \le 10\ \text{GeV} \\ 8E_T(m) < \xi\,(m) < -8E_{|T}(m) \;\text{ for }\; -1\ \text{GeV} < E_T(m) \le 0\ \text{GeV} \end{cases}$$

Commissioning : validating userCode blocks

1. Create **condition database** with **calibration coefficients** converted to integers
   ➔ Load it in LATOME registers

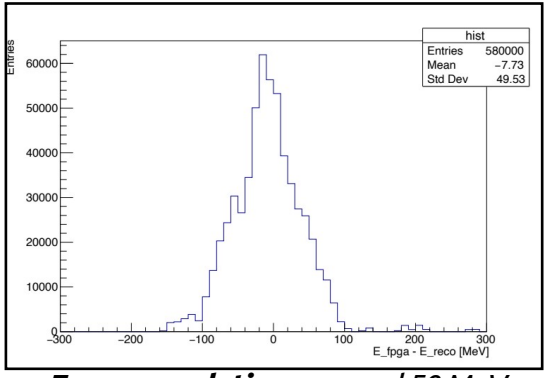
2. Check **energy** (E_T) **computation** by the LATOME is correct with a monitoring run :
   ➔ 1000 events each with 11 ADC (1 per Bunch Crossing) sent to each channels (=SuperCell) of LATOME boards (here 2 LATOMEs = 580 channels)
   ➔ Recompute $\mathbf{E_T}$ for each 8 first samples : 8x580 = **4640 $\mathbf{E_T}$/event computed**

3. Check **energy resolution:** LATOME E_T *vs* E_T computed with **full float precision**

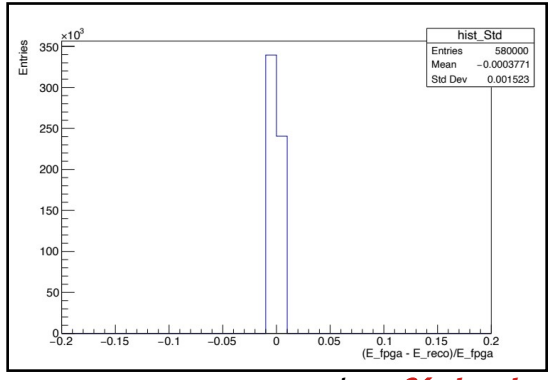
4. Enable **selection block** (E_T set to 0 upon failure) and repeat step 2
   ➔ Check $\boldsymbol{\xi = \tau \times E_T}$ computation AND selection criteria correct in LATOME

1 event: 11 ADC samples (consecutive BCs)

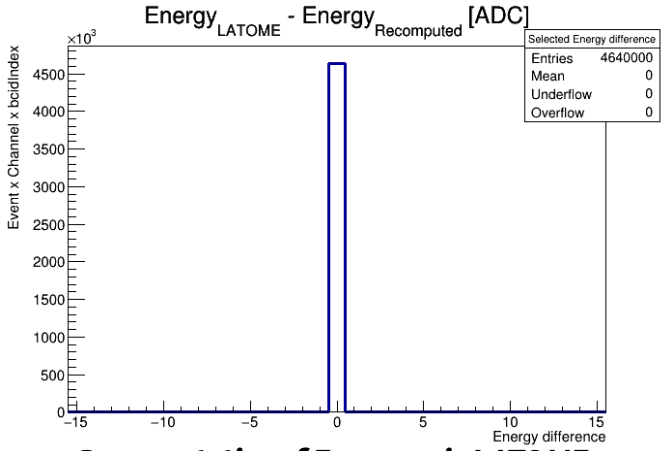
$$E_T(m) = \sum_{i=0}^{3} a_i \cdot (ADC_{m+i} - ped_{m+i})$$



Energy resolution : *around 50 MeV*



Energy accuracy : *At the **1 ‰ level***



Recomputation of Energy as in LATOME
ADC level (no factors to MeV level)
Selection block enabled

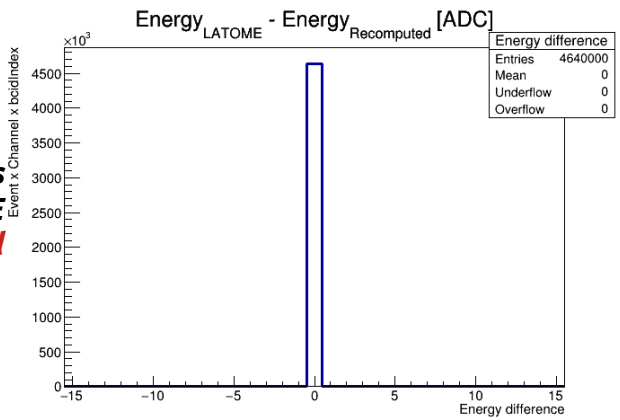
➔ ***Validated for these LATOMEs !***

Prospect : keep validating all blocks of UserCode on all LATOME boards (covering all SuperCells of LAr Calorimeter)

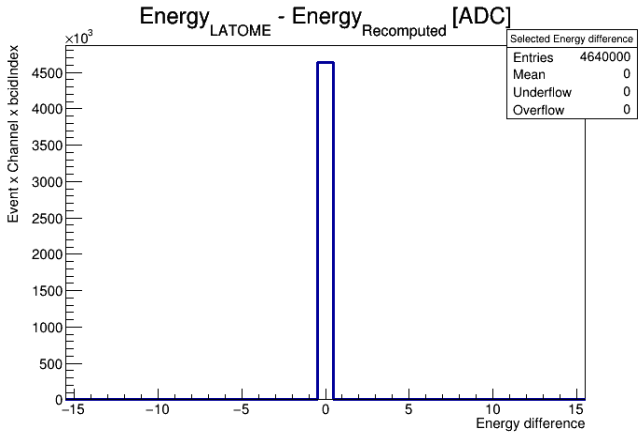
BACKUP SLIDES

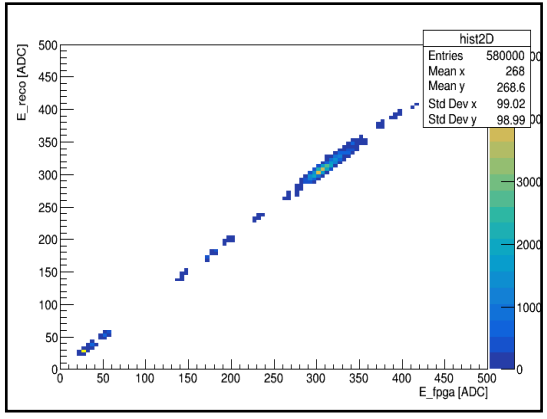
Energy in ADC counts

Recomputation of Energy as in LATOME
Selection Block ***disabled***

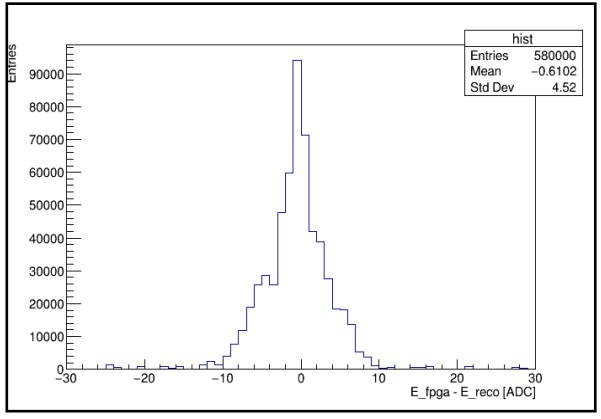


Recomputation of Energy as in LATOME Selection Block enabled

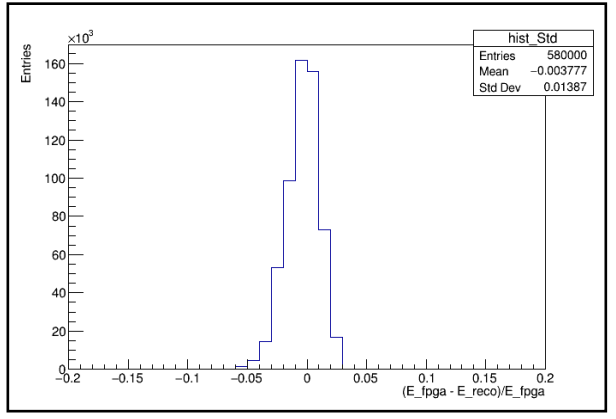




LATOME vs reco full precision Energy
good correlation



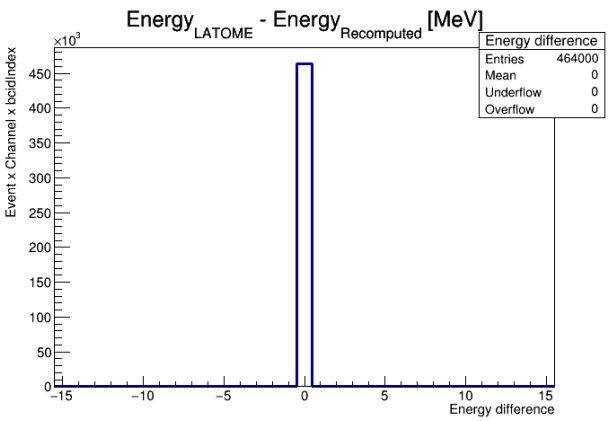
Energy resolution : *around 5 ADC*



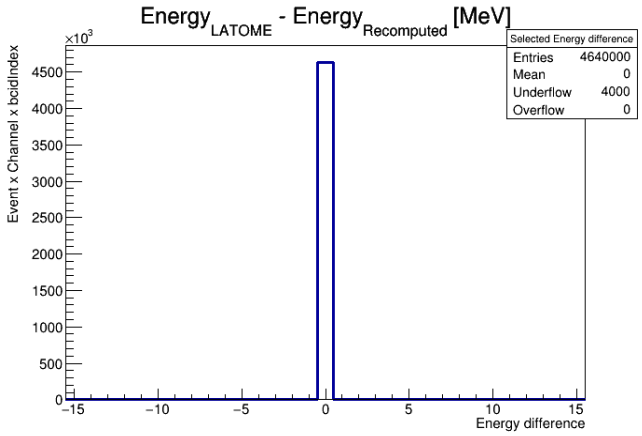
Energy accuracy : *At the 1 % level*

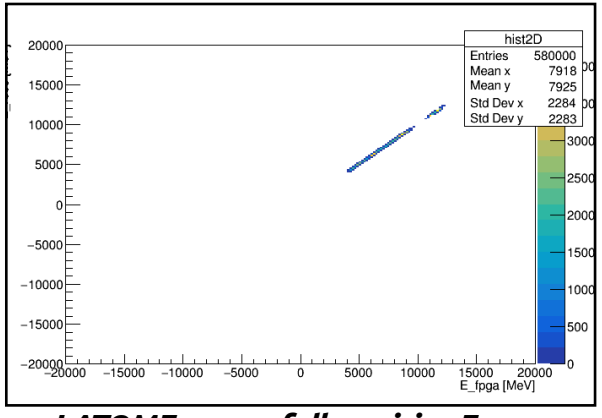
Energy in MeV

Recomputation of Energy as in LATOME
*Selection Block **disabled***



Recomputation of Energy as in LATOME
*Selection Block **enabled***





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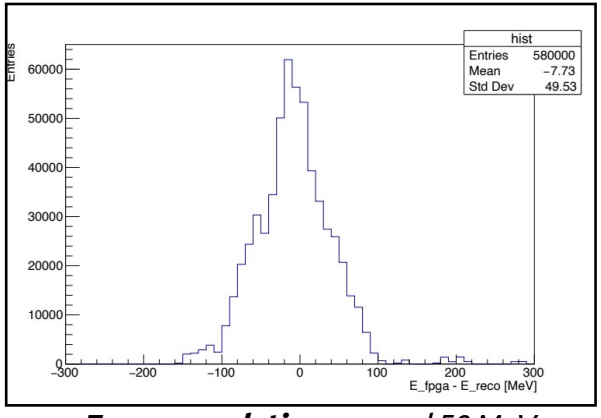
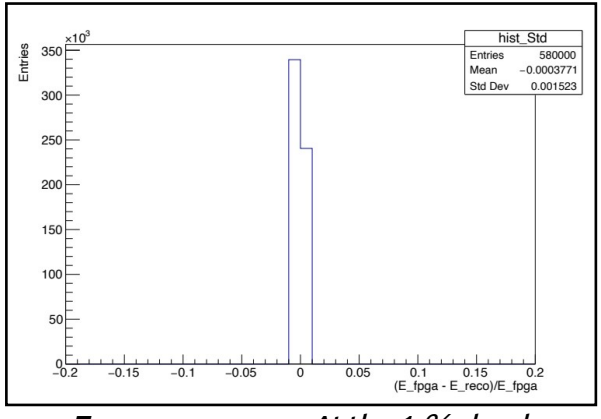


***Energy resolution :** around 50 MeV*



***Energy accuracy :** At the 1 ‰ level*