fFEX / overview

Slides by Adrian / Julian / Uli
for Mainz fFEXers

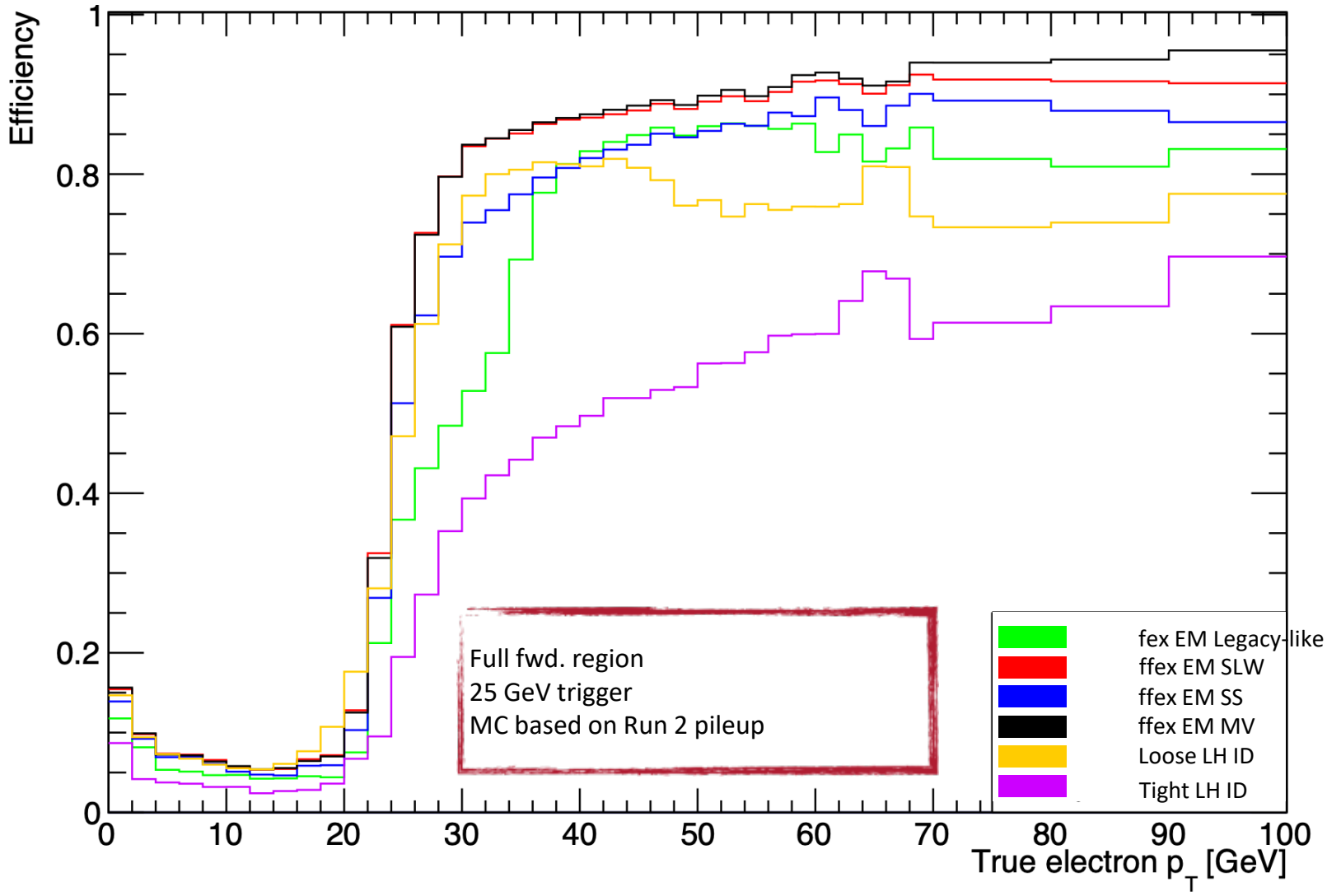
Introduction

- fFEX new addition to L0Calo (eFEX, gFEX, jFEX) trigger system for fwd. jets/EM objects
  - EM trigger ($\eta|>2.5$): interesting for fwd. electrons (e.g. $\sin^2\theta_W$)
  - Jet trigger ($|\eta|>3.2$): interesting e.g. for VBF processes
- Advantage: finer granularity than jFEX (full detector granularity)

fFEX crucial addition to L0Calo for precision measurements utilizing fwd. objects

EM trigger studies

Link for more details



'trigger energy scale' shifted to roughly match 'offline energy scale'

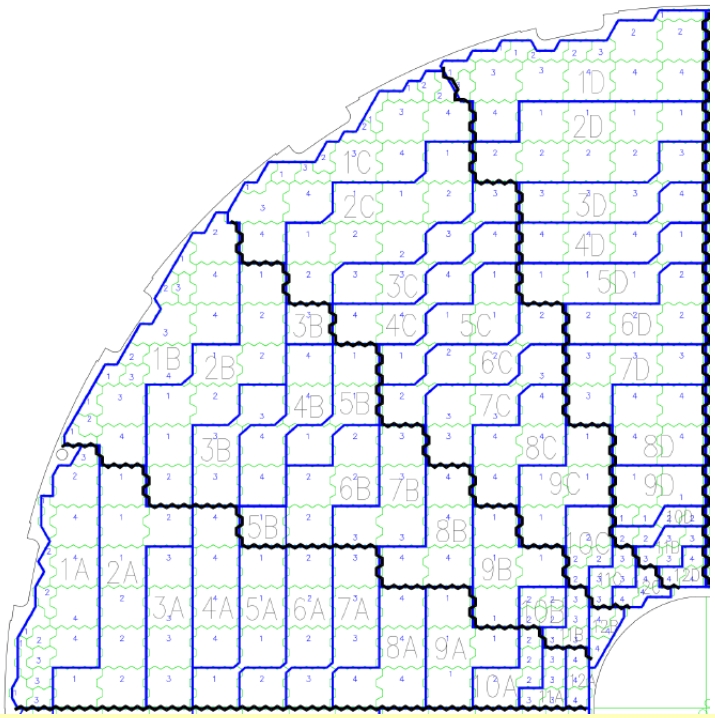
Baseline algorithms…

- Sliding window algorithms refined wrt Phase-1 modules
- Basic processing unit:
  - FPGA covering a quadrant in phi (core)
  - Requiring core data and environment
  - Environment provided by upstream duplication
    - From one neighbouring octant in phi each side
    - 100% duplication of all data
      → to separate data on fibres by octant

- … and beyond the baseline: more powerful ones for best possible background rejection on em objects…

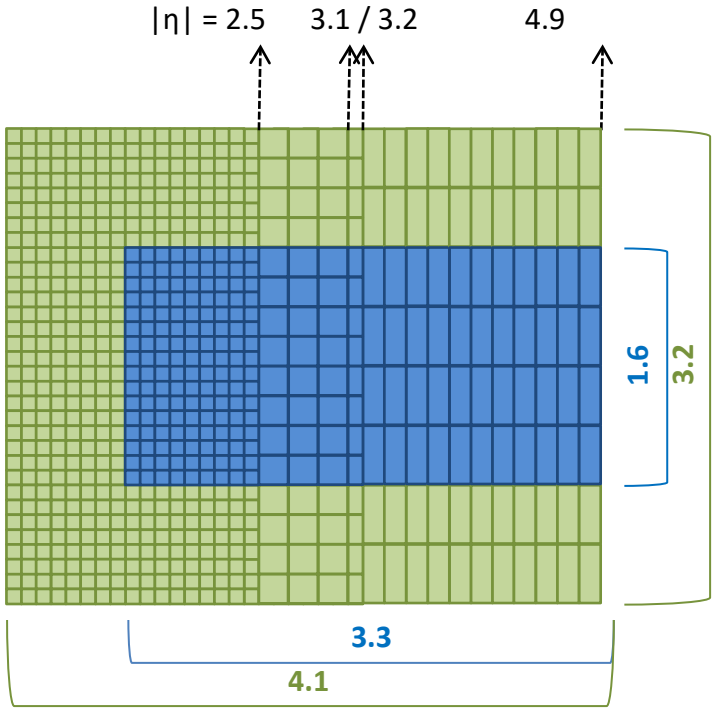
Jets at phase 1 → phase 2

- Sliding window algorithm basically at 0.1 x 0.1 (eta, phi)
  - Regular towards small eta
  - Irregular in forward region (cell geometry)
    - Find local maximum in a sliding window
    - Sum up energies in a given environment → jet



Super Cell

jFEX forward module



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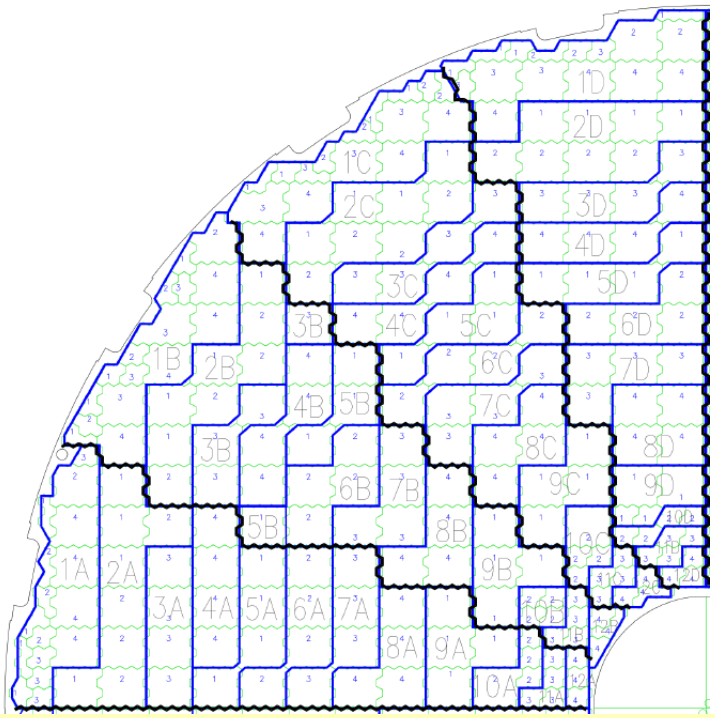
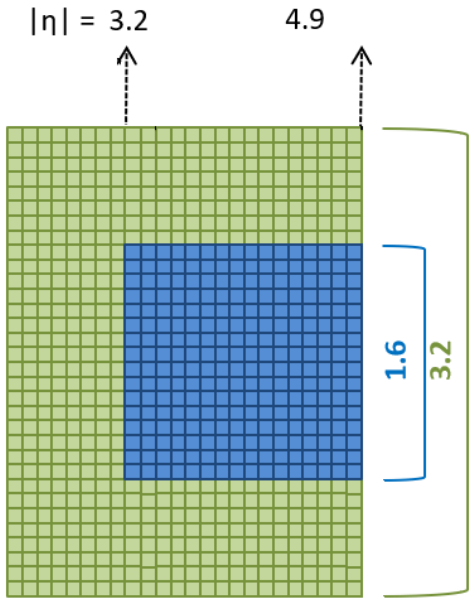




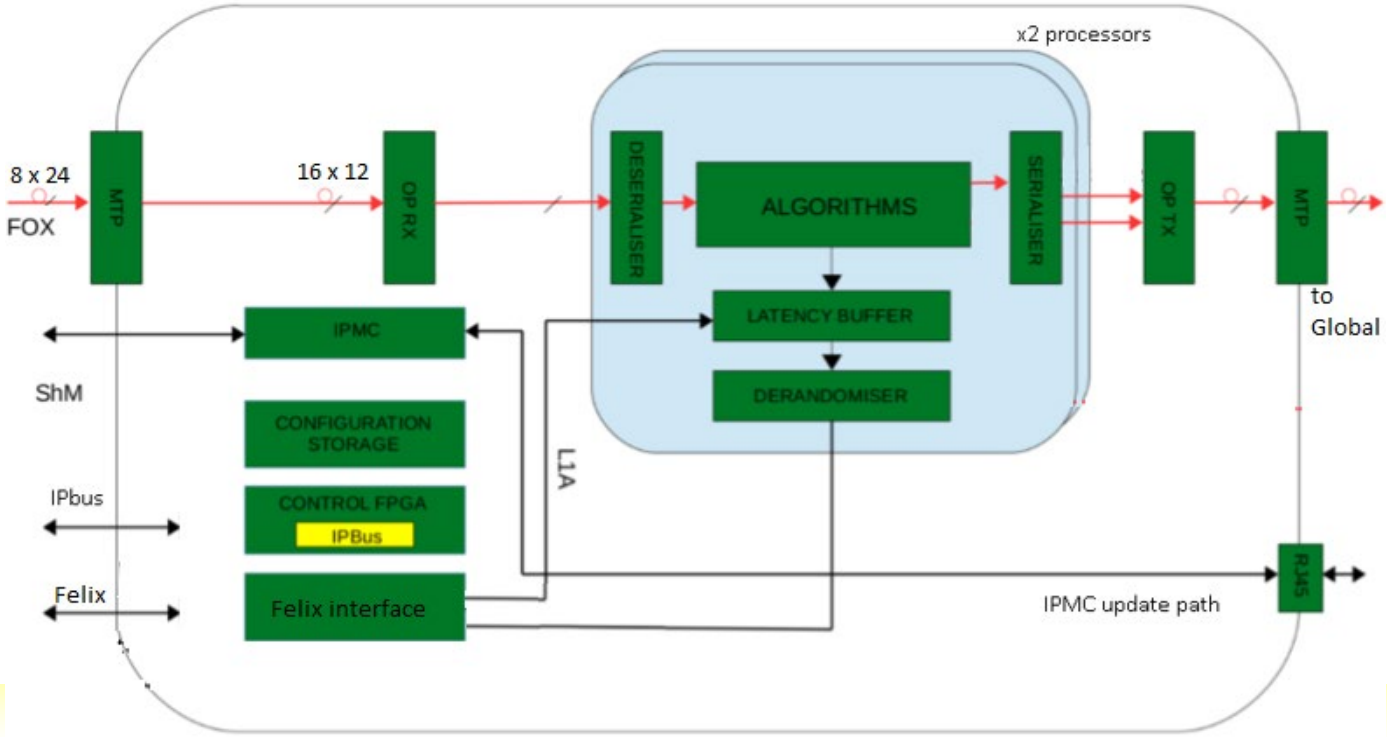
fFEX
true cell positions
to be used in f/w

Mapping data onto fibres

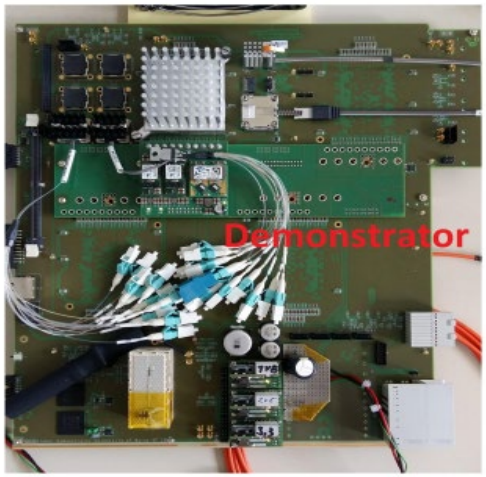
- Assuming 25Gb/s opto fibre links
- Cell level information for core data, some pre-summing for eta environment only
- 100% duplication (basically half a detector side worth of data into each FPGA)
- Initial estimate at ~65 fibres per FPGA (ie. quadrant)
- More recent estimates ~80 → 96 abs max.
- Mapping exercises ongoing
  - Data bits per cell (encoding, see below)
  - Payload vs. bitrate (protocol)
    - End-to end synchronized to LHC clock !
    - Interlaken
    - Hermes
    - …
      → Go for common protocol with LAr/Global interface if possible

fFEX Module

- ATCA module derived from Phase-1 modules (jFEX, L1Topo)
  - Four modules total
  - Two FPGAs per module (baseline XCVU13P)
  - Large numbers of high speed links per FPGA
    → large number of (Firefly) opto devices (12-way)



- Equivalent to half a jFEX, with higher speed links…
  … as explored on U. Mainz L0Global/fFEX technology demonstrator



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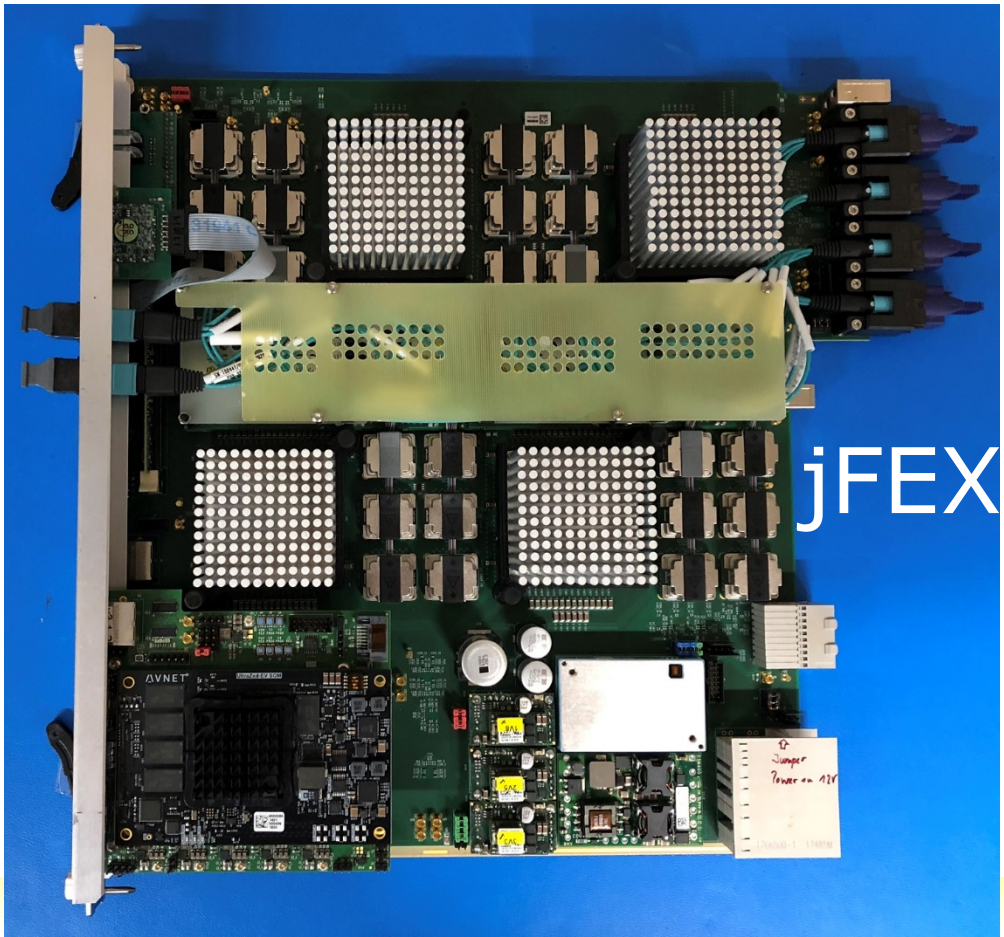

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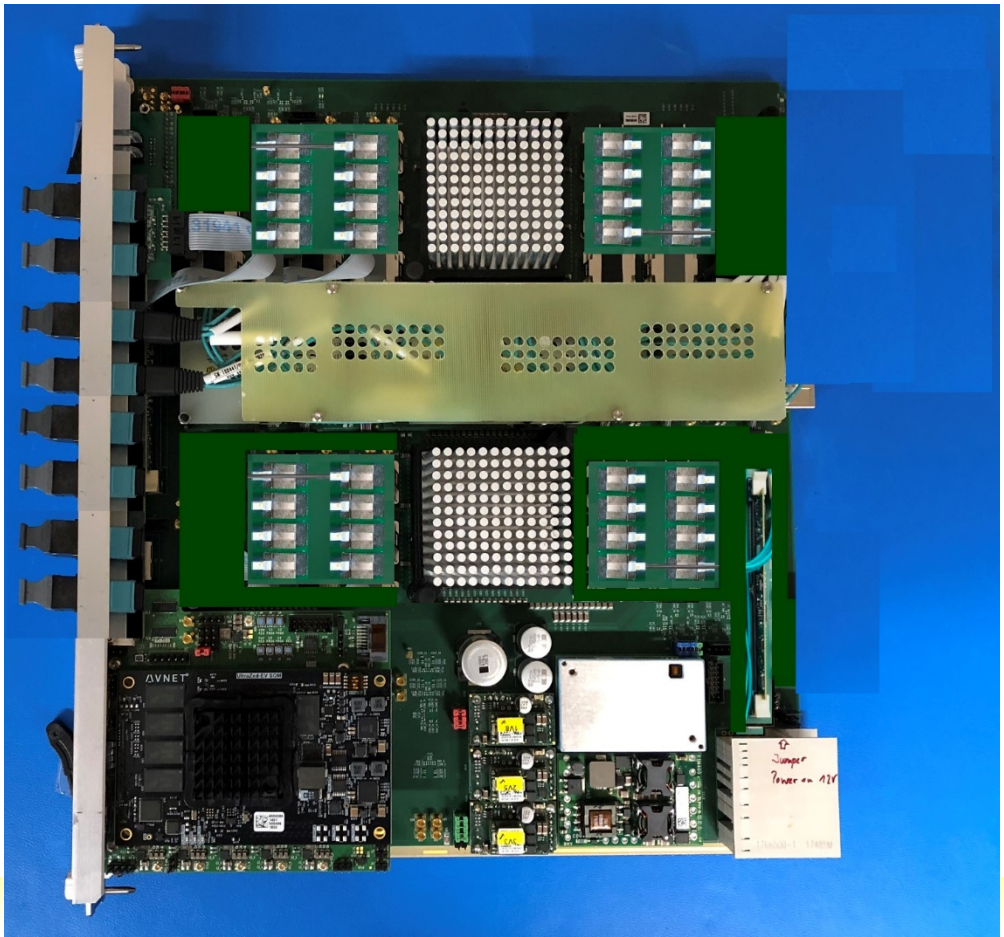


Status and work in progress

- Work on
  - Module design
    - block diagram level
    - some detailed design: jFEX/L1Topo building blocks
  - Documentation
    - Interfaces !!!!
    - Iterate on LAr/fFEX mapping
    - Aim at participation in link/protocol test activities
    - Energy encoding : 11-bit, multi-linear (see below)

fFEX encoding

- Information of cell E_T transmitted between LAr →fFEX
- Multilinear encoding scheme
  - Independent for each detector region (EMEC, HEC, FCal)
    - Separating between some layers also considered
  - Cover a large energy range (maximum ~500 GeV)
  - Include negative energy values
    - Level of PU noise used to estimate the minimum energy
  - Minimum granularity comparable to the electronics noise
    - Energy range size of other linear regions proportional to the minimum
- Optimisation of the scheme ongoing
  - Figure of merit used is the ratio between the stochastic error after/before encoding
  - Number of linear regions and their size are the variables to optimise

→ 'Keep it simple, but don't compromise on physics performance'

fFEX encoding example: EMEC 1 scheme (6 linear regions)

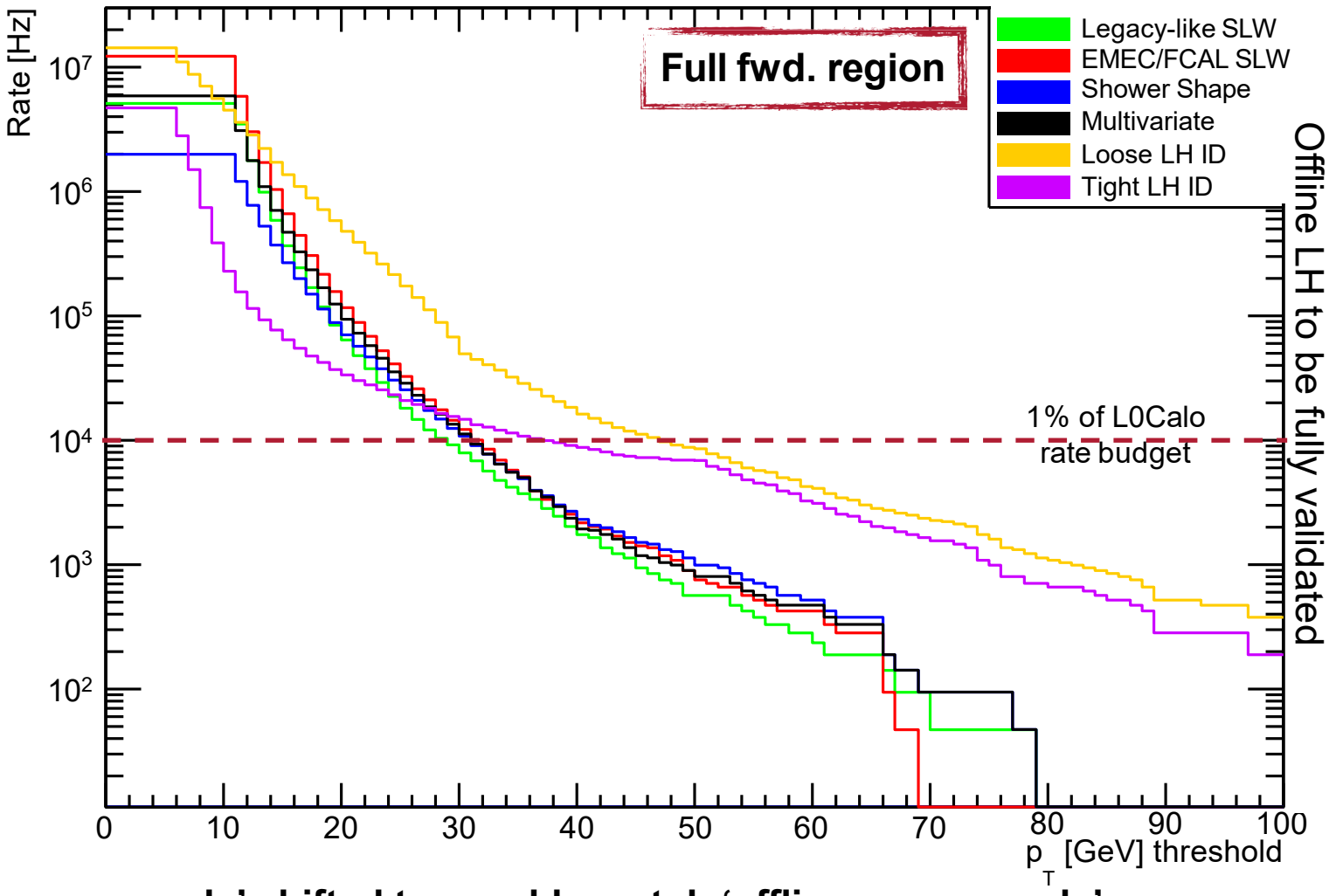
Code	Energy range in MeV	Range size in MeV
0	No data available	-
1	< -5000	-
2	[-5000, -4984)	16
...	...	...
251	[-1016,-1000)	16
252	[-1000, -996)	4
...	...	...
751	[996, 1000)	4
752	[1000, 1016)	16
...	...	...
776	[1384, 1400)	16

Code	Energy range in MeV	Range size in MeV
777	[1400, 1464)	64
...	...	...
1231	[30456, 30520)	64
1232	[30520, 30776)	256
...	...	...
1676	[144184, 144440)	256
1677	[144440, 145464)	1024
...	...	...
2041	[517176, 518200)	1024
2042	> 518200	-
Rest	Reserved	-

Simplifications and optimisation of the encoding scheme ongoing

Backup

Rates



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Optimising the encoding scheme

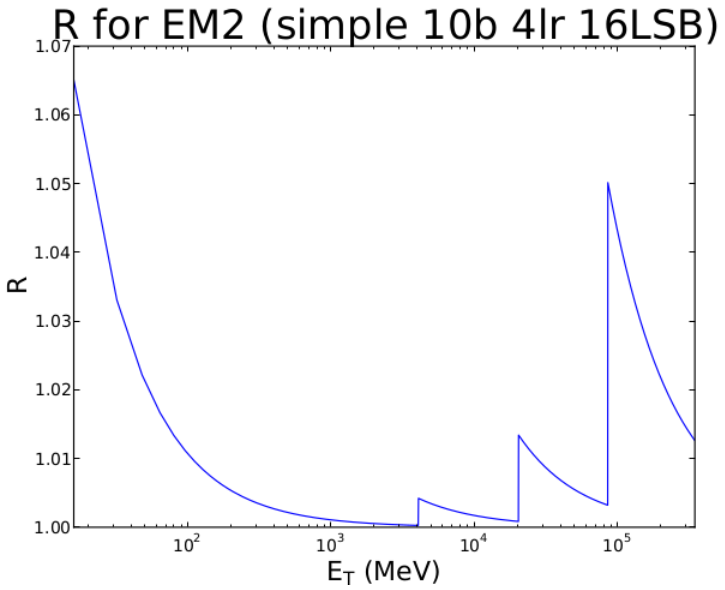
The figure of merit used is the ratio between the stochastic error (sampling term) after/before encoding

$$V = kE_T \ (linear\ encoding)$$
$$\sigma_v = k\sigma^s \ , where\ \sigma^s = a\sqrt{E_T}$$
$$\sigma_v = ka\sqrt{E_T} \ , \ \sigma_Q = \frac{1}{\sqrt{12}}$$
$$\sigma_v^{total} = \sqrt{k^2a^2E_T + \frac{1}{12}}$$
$$\sigma^{E_T\,Reco} = \frac{\sigma_v^{total}}{k} = a\sqrt{E_T}\sqrt{1 + \frac{1}{12k^2a^2E_T}} = \sigma^s R$$

$$R = \sqrt{1 + \frac{1}{12k^2a^2E_T}} \ ,$$

a ~ 0.1 for EMEC
0.7 for HEC
0.3 for FCal 1
1 for FCal 2 and 3

$$k = \frac{2^n - 1}{E_T^{max}}$$



Look for the scheme which minimises R → Scan over many possible schemes

Previous FEXes encoding studies used R as well