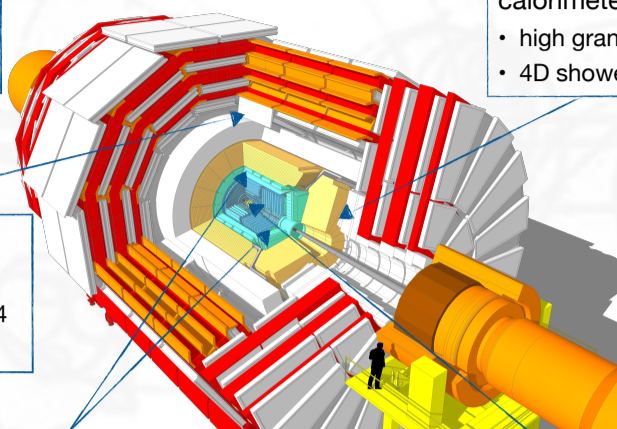


## The CMS Phase II upgrades

**Trigger/HLT/DAQ**

- track information at L1
- L1 increased to 750 kHz
- HLT rate increased to 7.5 kHz



**new endcap calorimeters (HGCAL)**

- high granularity
- 4D showers

**muon systems**

- new electronics
- RPC coverage up to  $|\eta| < 2.4$
- GEM up to  $|\eta| < 3$

**new precision timing detector**

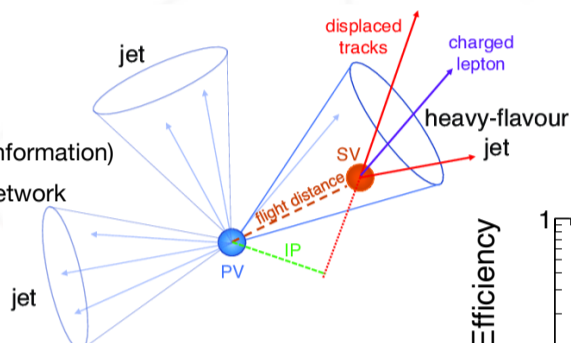
- timing resolution of 30-40 ps for MIPs
- full coverage of  $|\eta| < 3.0$

**new inner & outer tracker**

- coverage to  $|\eta| < 4$
- track-trigger @ 40 MHz

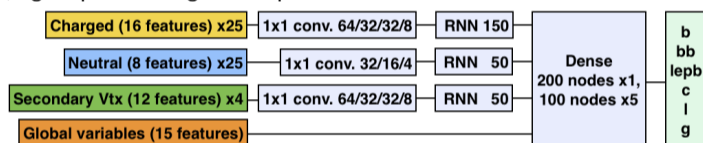
### DeepCSV

- successfully used through Run II data taking
  - 2018 deployed at HLT
- high-level inputs (jet, track, secondary vertex information)
- fully-connected feed-forward multi-classifier network
  - b, c, light quark separation

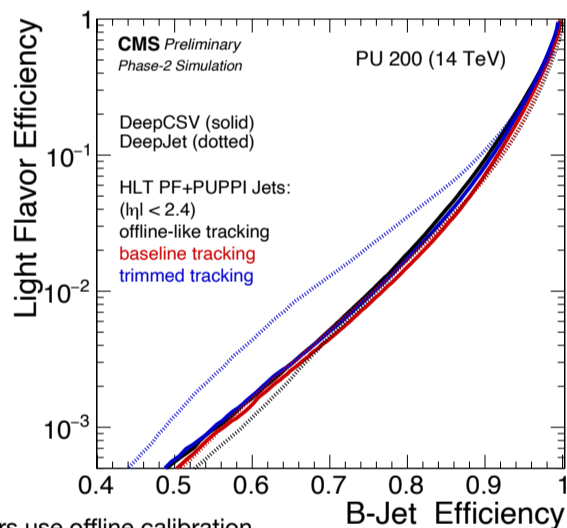


### DeepJet

- state-of-the-art tagger
- combining high + low level inputs
- convolutional, recurrent and fully-connected layers
  - b, c, light quark and gluon separation



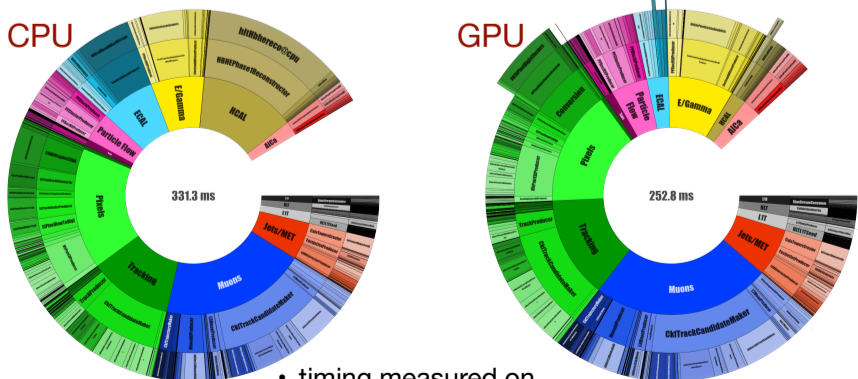
First time tested at HLT!



- both taggers use offline calibration
- DeepJet highly affected by differences in input variable shapes
  - to be improved in the future with **dedicated recalibration**
- future developments:
  - suitable incorporation of timing detector information into tagger architecture
  - exploring new architectures, e.g. graph networks
  - **optimisation for GPU**

## GPU offloading (Run 3)

### Demonstrating future timing improvements



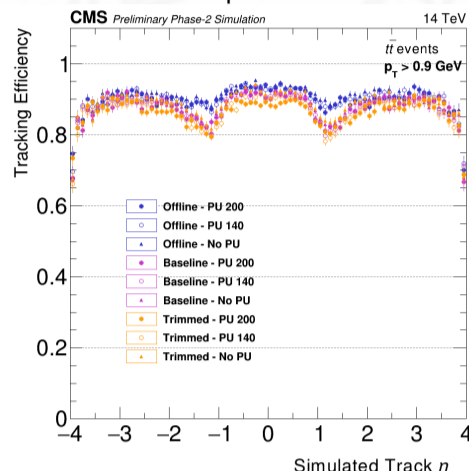
- timing measured on
  - CPU: 2x AMD "Rome" 7502
  - GPU: 2x AMD "Rome" 7502 + Nvidia T4

## Heavy flavour tagging at HLT

### reconstructed tracks

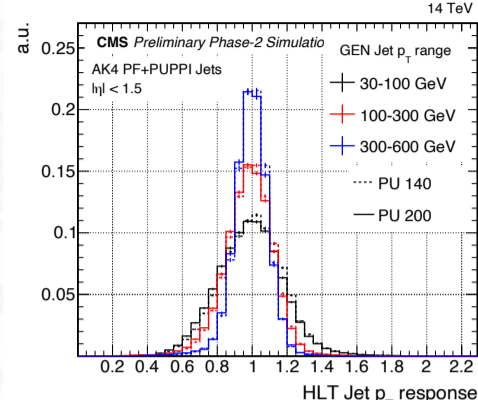
Iterative tracking approach:

- HLT baseline with two iterations
- **six times faster wrt. offline**
- stable performance wrt. pileup
- trimmed configuration shows further 30-40% timing reduction using tracking regions around selected pixel vertices



### Inputs

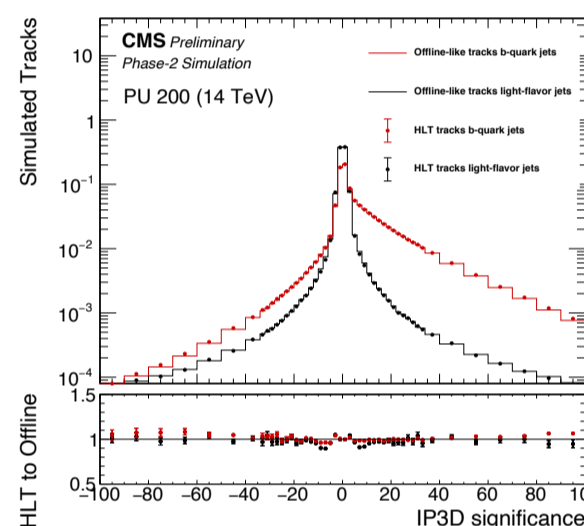
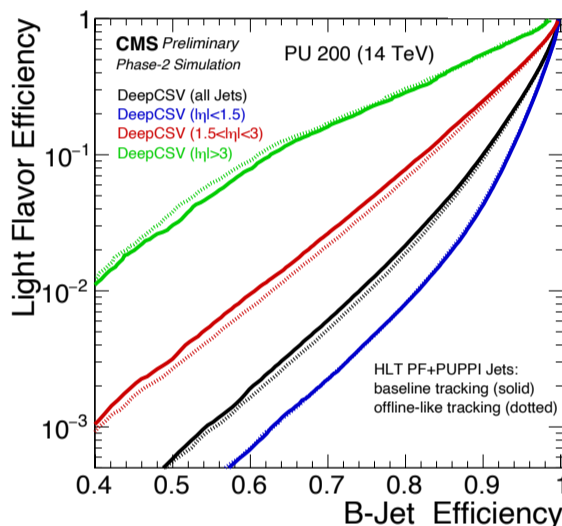
### reconstructed jets



Hadronic jets using particle-flow (PF) approach:

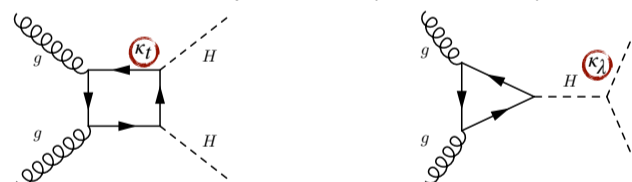
- anti- $k_T$  with  $R = 0.4$
- pileup mitigated by using Pileup Per Particle Identification (PUPPI)
  - weights derived for each particle candidate to come from hard scattering
- **good jet response up to pileup 200**

### Similar performance between offline and HLT!



## Realistic HLT paths for the HL-LHC

### SM production (non-resonant)



### Studying Di-Higgs production for flagship analyses at HL-LHC

SM relevance:

- main diagrams with destructive interference
- Higgs self coupling

BSM relevance:

- searches for heavy particles decaying to HH

- designed two paths with fixed HLT output rate of 75 Hz
- L1 trigger used: QuadJet +  $H_T$
- b-tag only option highly efficient for  $m_{HH} > 400$  GeV
  - **excellent for SM/BSM physics contexts**
- time-wise more challenging to higher tracking input rate
  - future improvements and GPU deployment

#### Run 2 - like:

- 4 jets with  $p_T > 75, 60, 45, 40$  GeV
- $H_T > 330$  GeV
- at least 3 jets b-tagged with DeepCSV  $> 0.33$

#### b-tag only:

- 4 jets with  $p_T > 70, 40, 30, 30$  GeV
- $H_T > 200$  GeV
- at least 3 jets b-tagged with DeepCSV  $> 0.39$

