

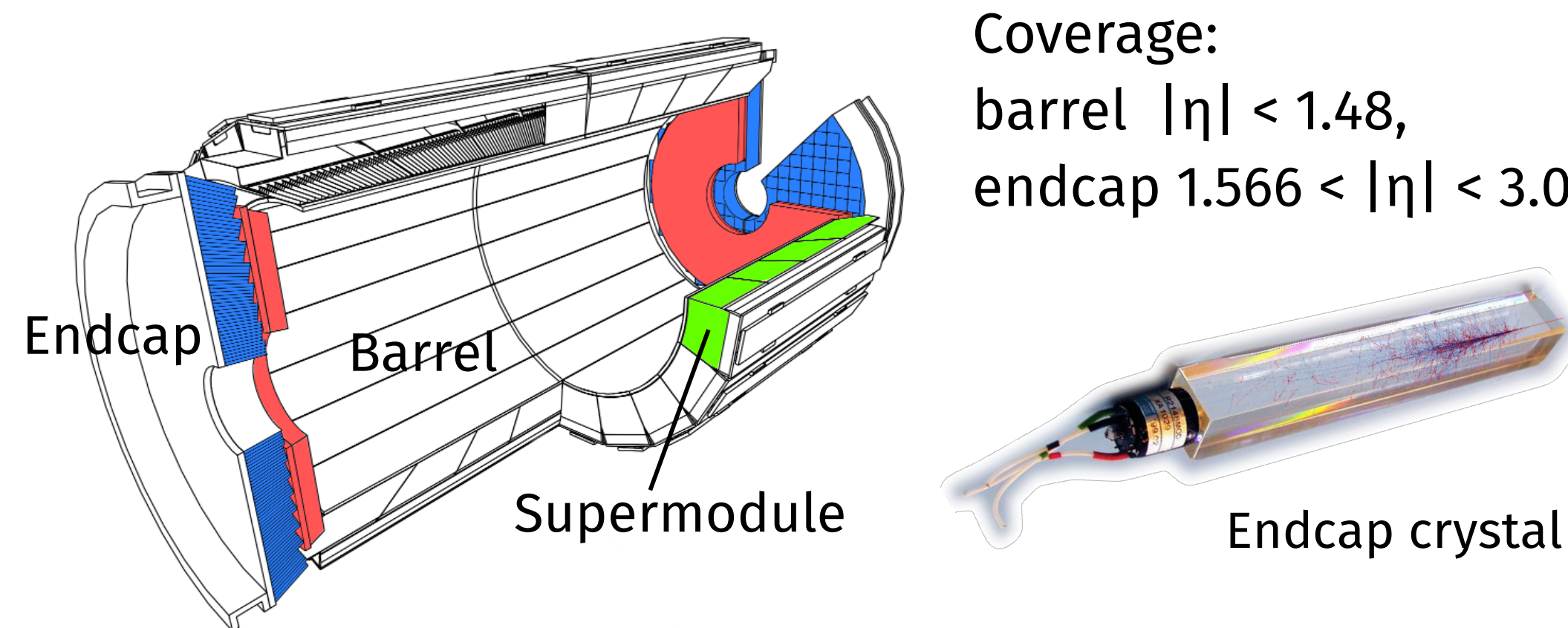
Optimising the performance of the CMS Electromagnetic Calorimeter to measure Higgs properties during Phase I and Phase II of the LHC

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The Electromagnetic Calorimeter (ECAL)

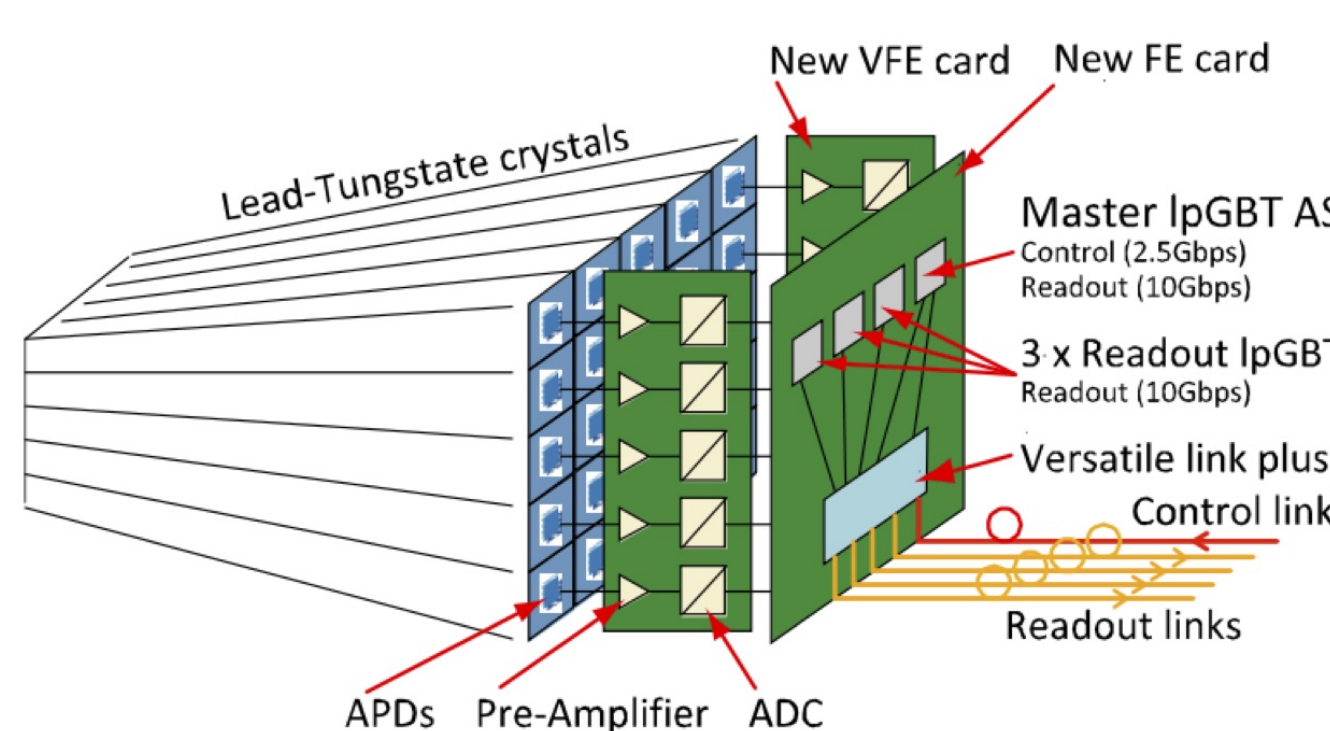
- Homogenous and hermetic calorimeter
- Precisely measures the energy of γ , e^+ , e^-
- Key part of CMS Higgs boson observation ($H\gamma\gamma + ZZ^*4l$)
- Scintillating lead tungstate ($PbWO_4$) crystals: 61,200 barrel, 14,648 endcaps



HL-LHC upgrade requirements

- Up to ~ 4000 /fb delivered at the end of HL-LHC
- Peak pileup events: 200
- Level1 Trigger latency: $3.8 \mu s \rightarrow 12.5 \mu s$
- Level1 Trigger rate: $100 kHz \rightarrow 750 kHz$

ECAL keeps only barrel crystals and photo-detectors (APD). All electronics replaced to **reduce the noise**, improve **timing resolution** and provide **crystal information** to the L1 trigger (instead of 5x5 energy as in Phase I system).



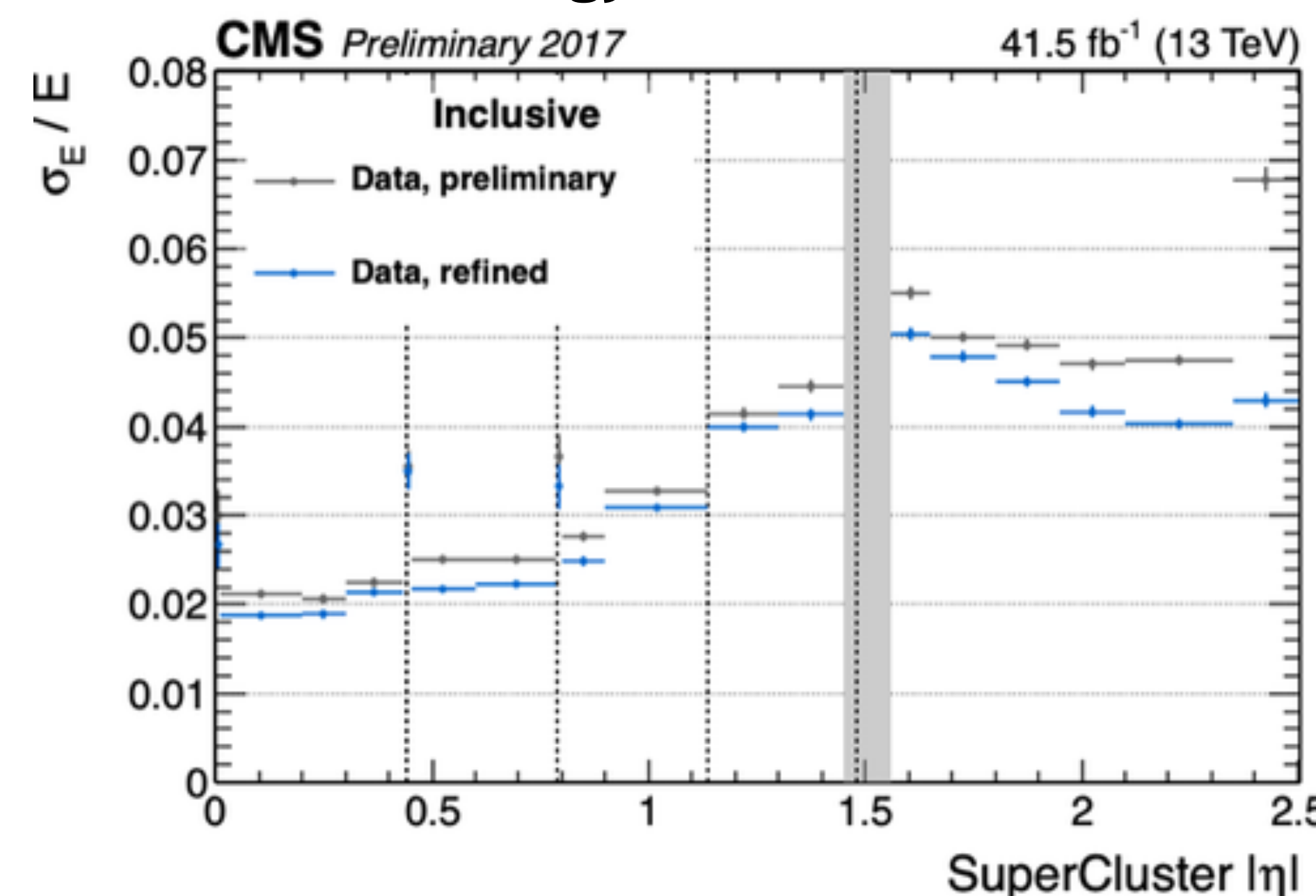
LHC Run II Performance

Reconstruction and calibration procedures implemented by ECAL to maintain **excellent energy resolution** and sustain the transparency loss and noise increase caused by **radiation damage** during LHC Run II (~ 150 /fb).

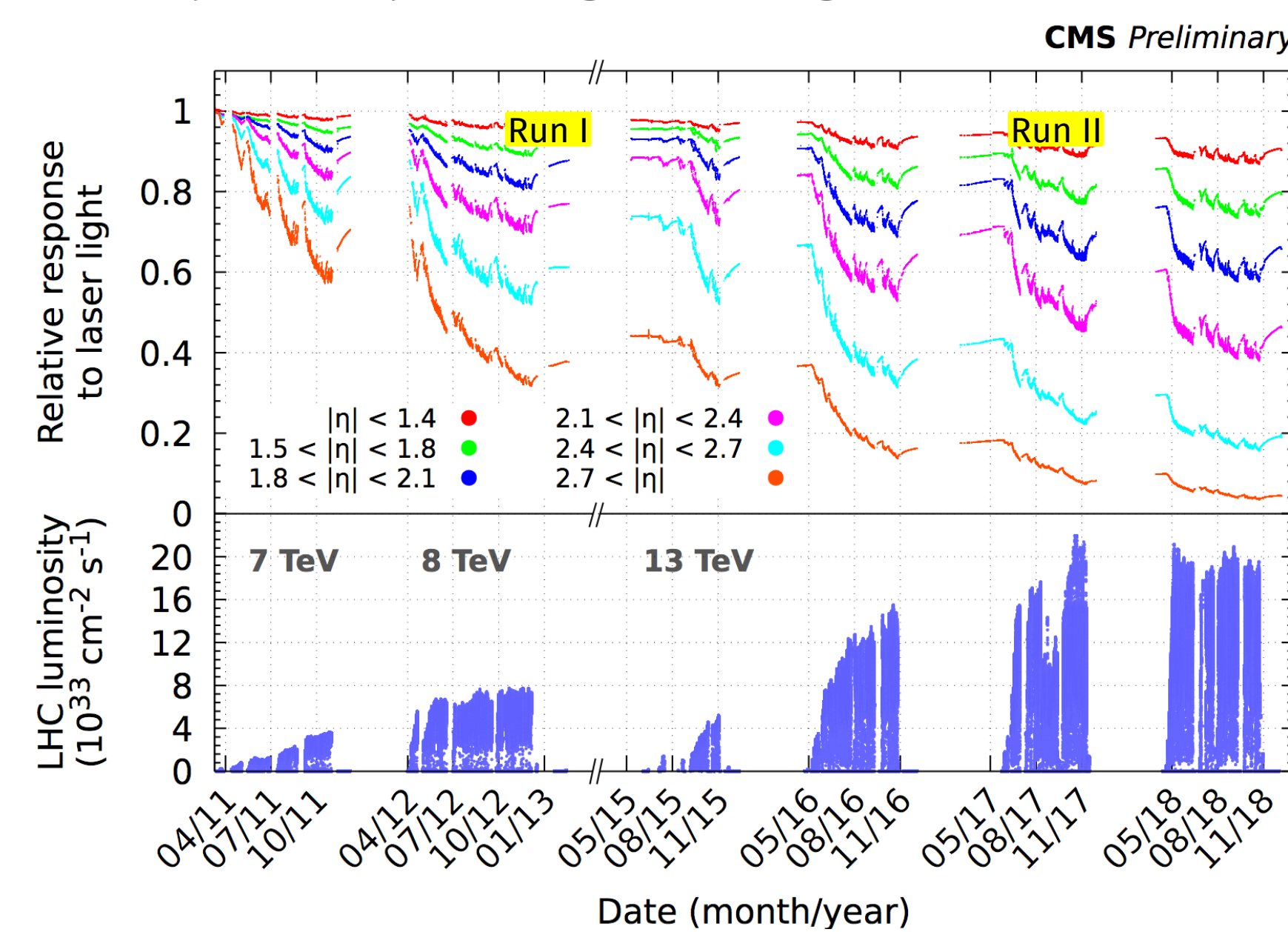
- Pileup aware local reconstruction
- Response monitored with laser light
- Channel-to-channel intercalibration exploiting well known physical processes: π_0 decay, Zee events, ratio of ECAL energy to tracker momentum.
- Absolute energy scale using Zee mass peak as reference

After the end of Run II, ECAL has performed a full re-calibration to deliver refined conditions with full time granularity for precision measurements.

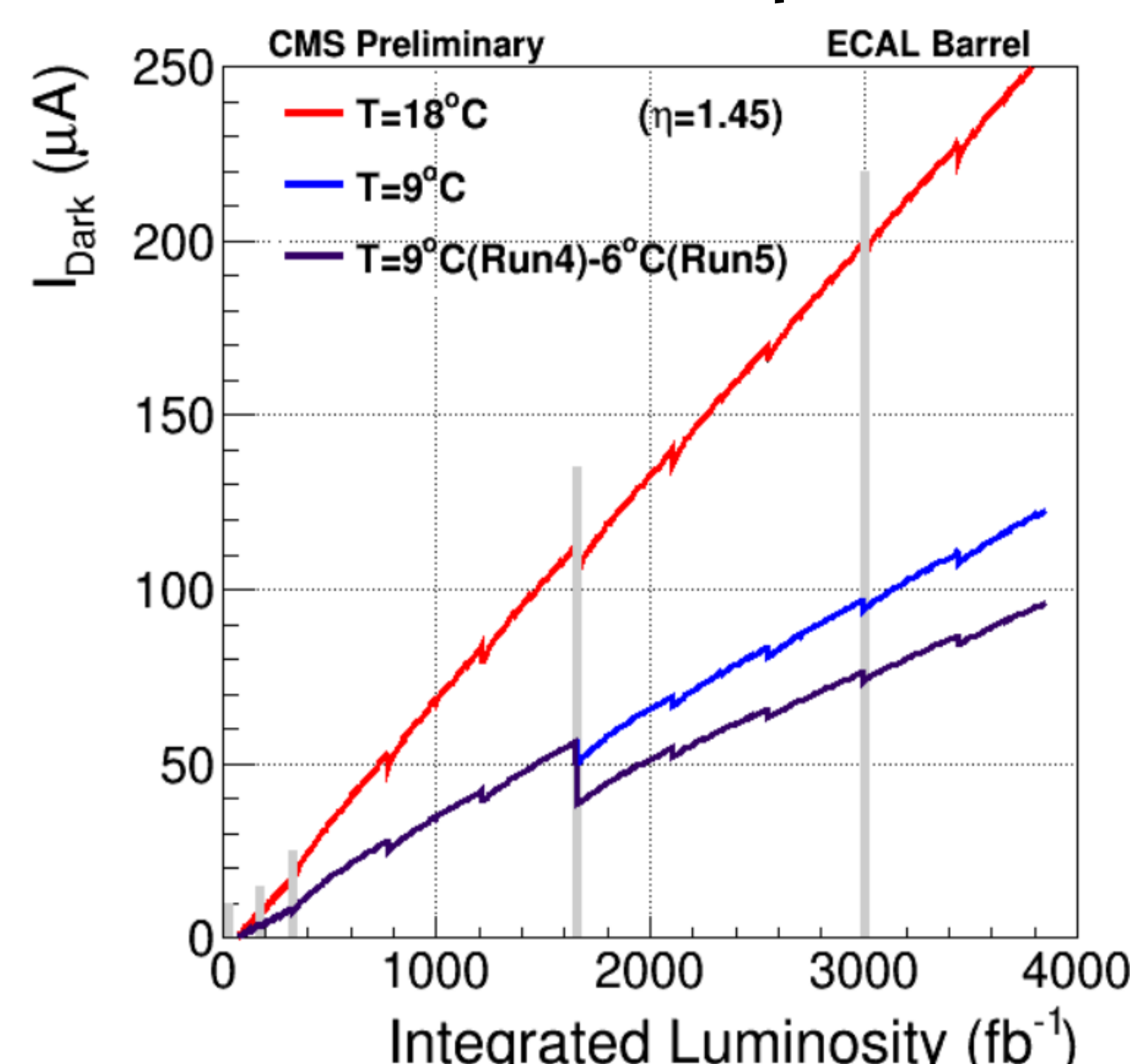
Energy resolution



Transparency change during RunI and RunII



APD dark current prevision



ECAL Barrel upgrade

Challenges

- Loss of crystal transparency
- Increase of dark current in APDs
- Spike* rate too high
- 200 PU interactions

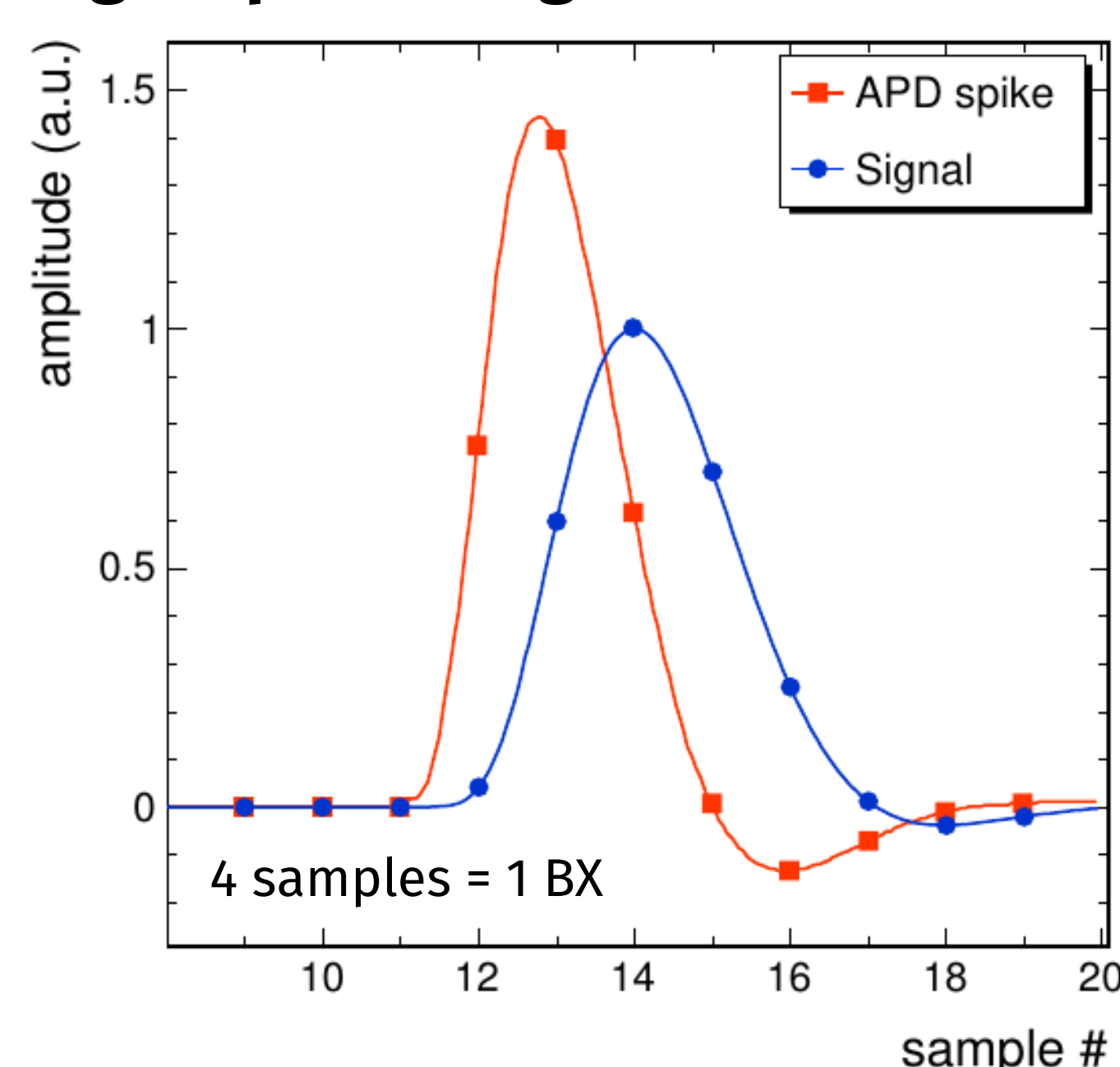
Goals

- Noise reduction
- Spike suppression
- Pileup mitigation
- Precise timing

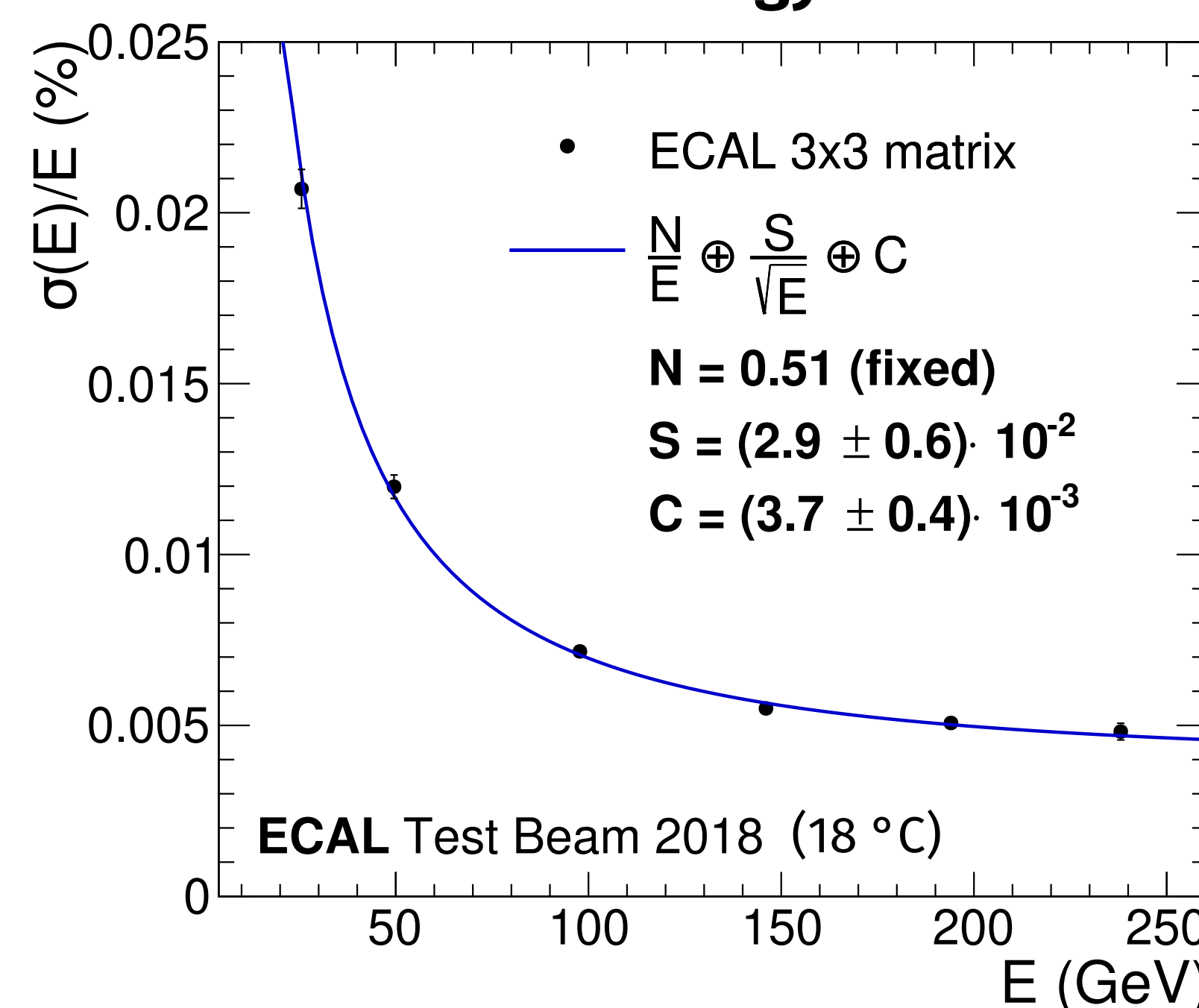
Actions

- Operating temperature: $18^\circ C \rightarrow 9^\circ C$
- New amplifier + ADC:
 - Decrease shaping time
 - Increase sampling rate $40 MHz \rightarrow 160 MHz$

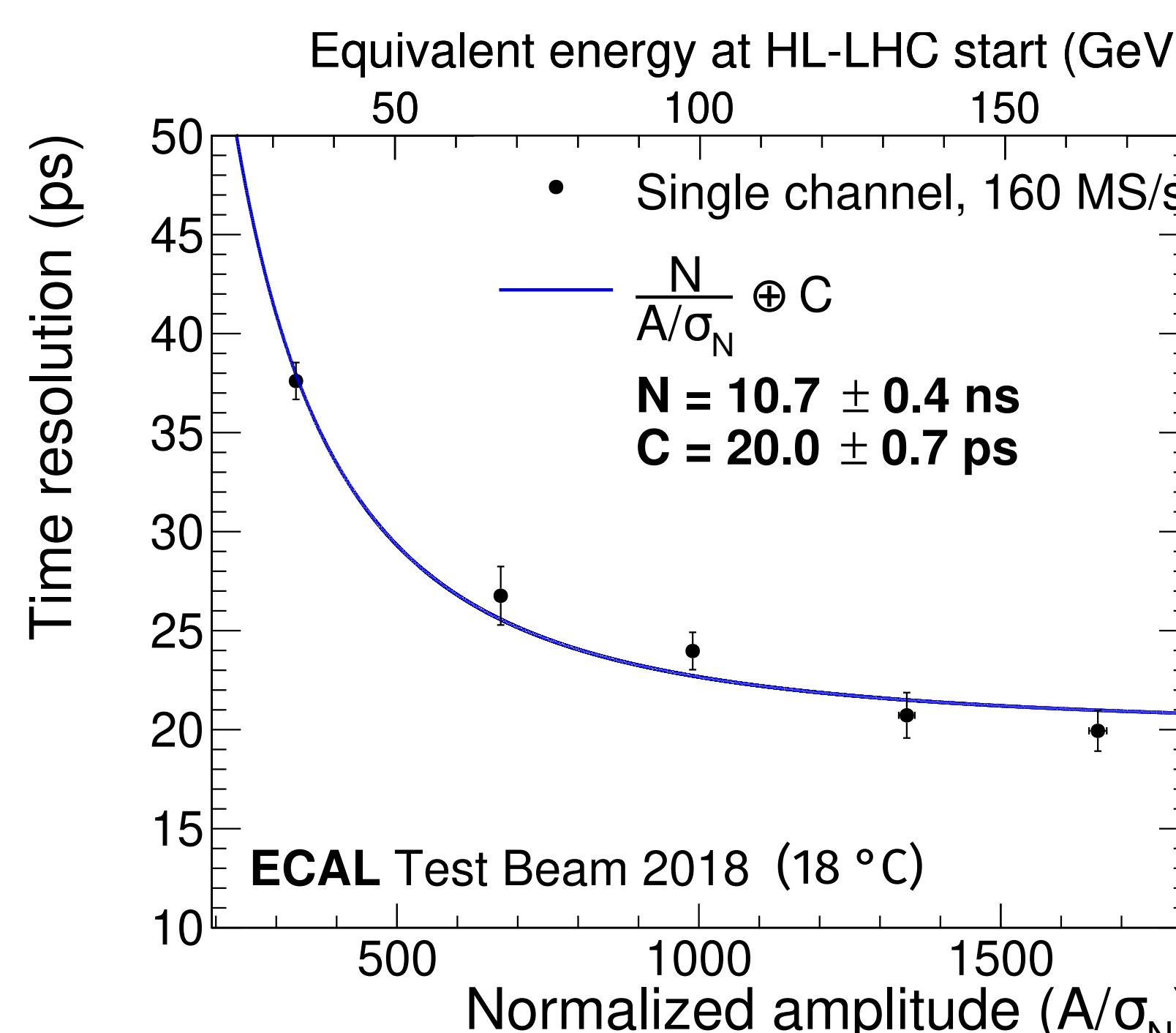
Signal pulse length: 10 BX \rightarrow 2 BX



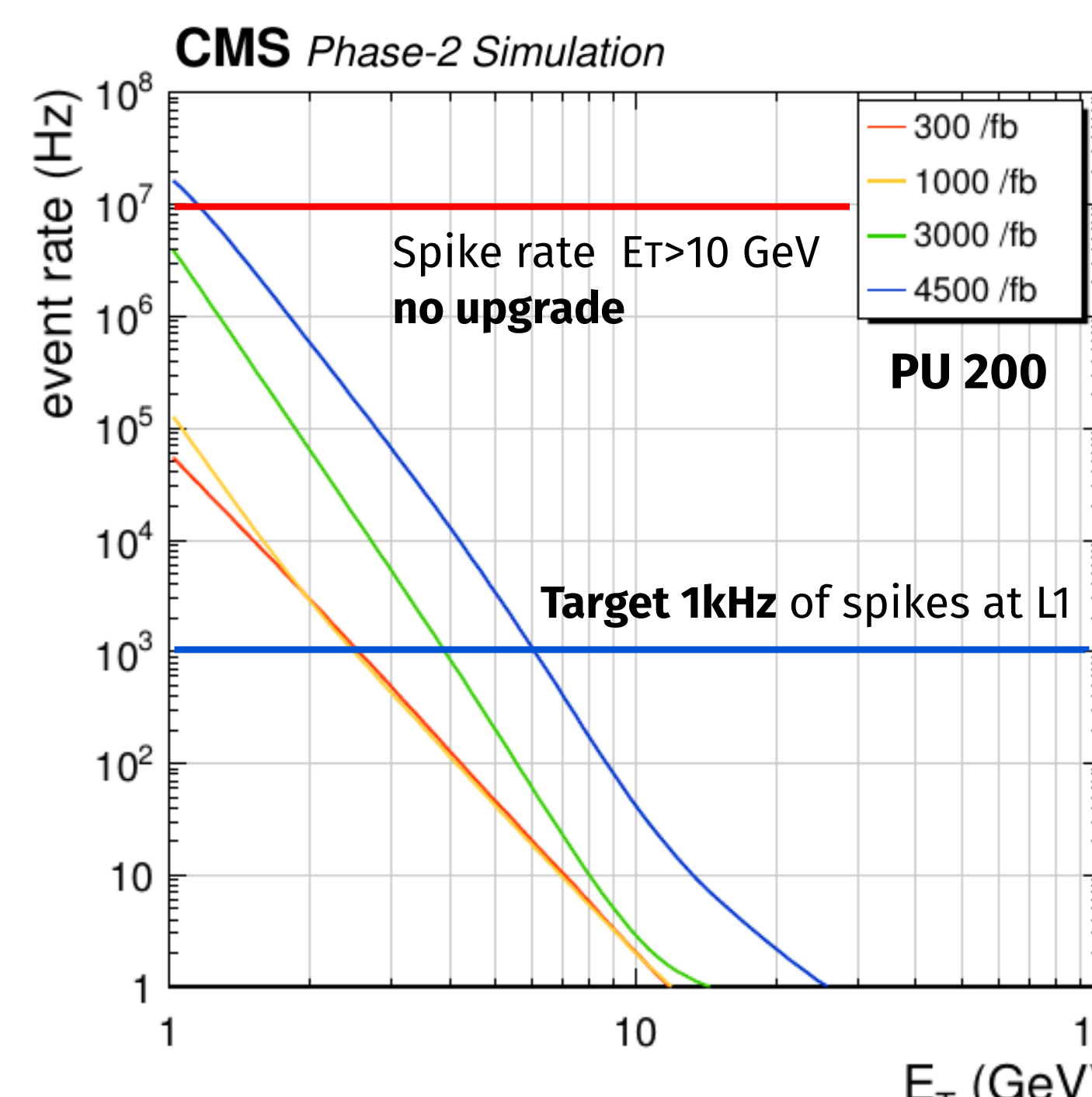
Test-beam energy resolution



Test-beam time resolution



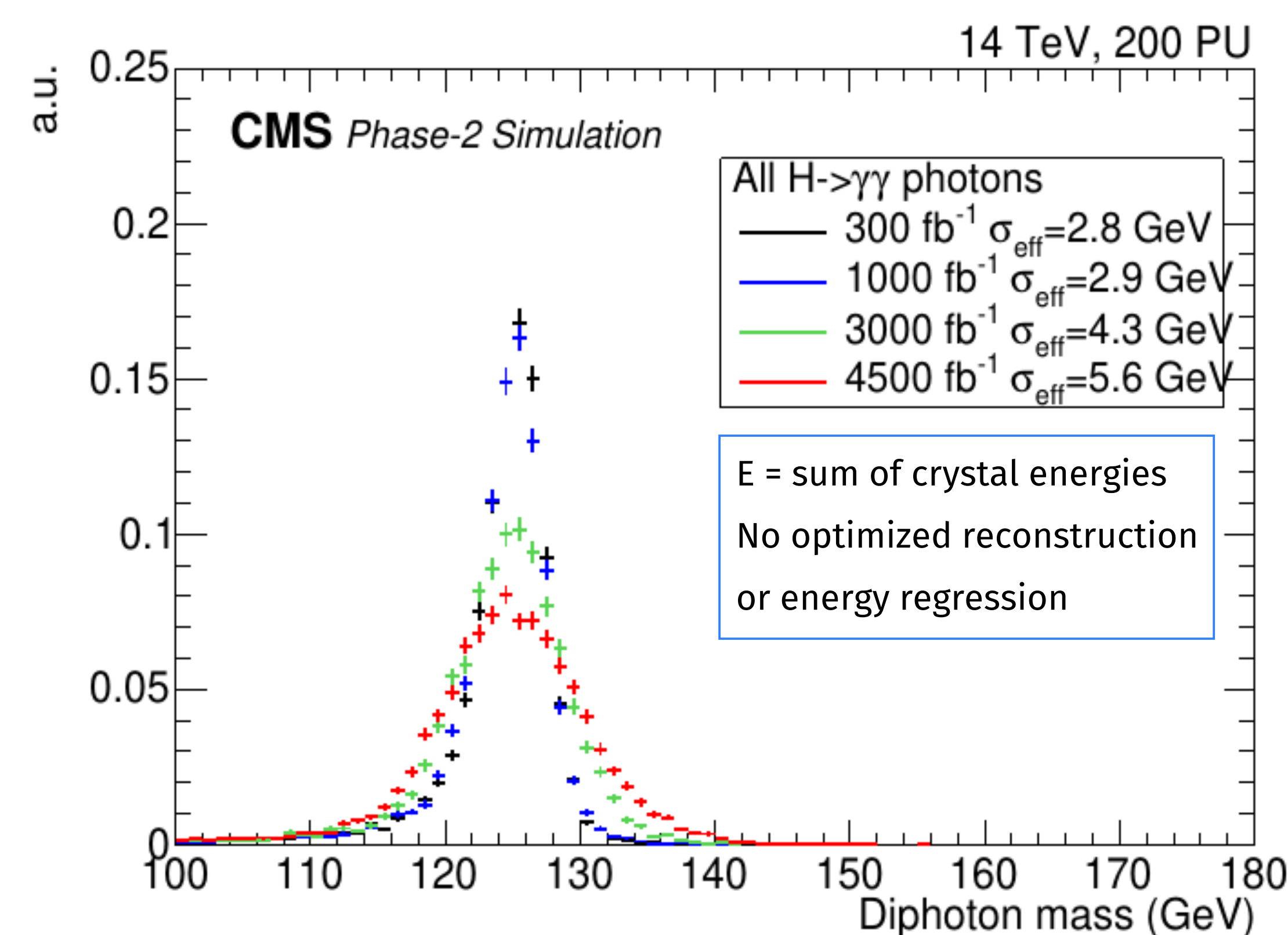
Spike rate above E_T threshold



*Spike: signal from direct APD ionization. Discriminated by ratio of subsequent samples.

Phase II Higgs performance

Thanks to EB upgrade the resolution on photons pairs reconstructed mass will only slowly decrease with integrated luminosity and **Phase I like performance will be maintained**.



The EB timing resolution will **increase vertex identification efficiency** at high PU, keeping under control the contribution of the angle between the photons to the mass resolution.

CMS Projection

3000 fb⁻¹ (13TeV)

