CMS Progress Report: Computing Part

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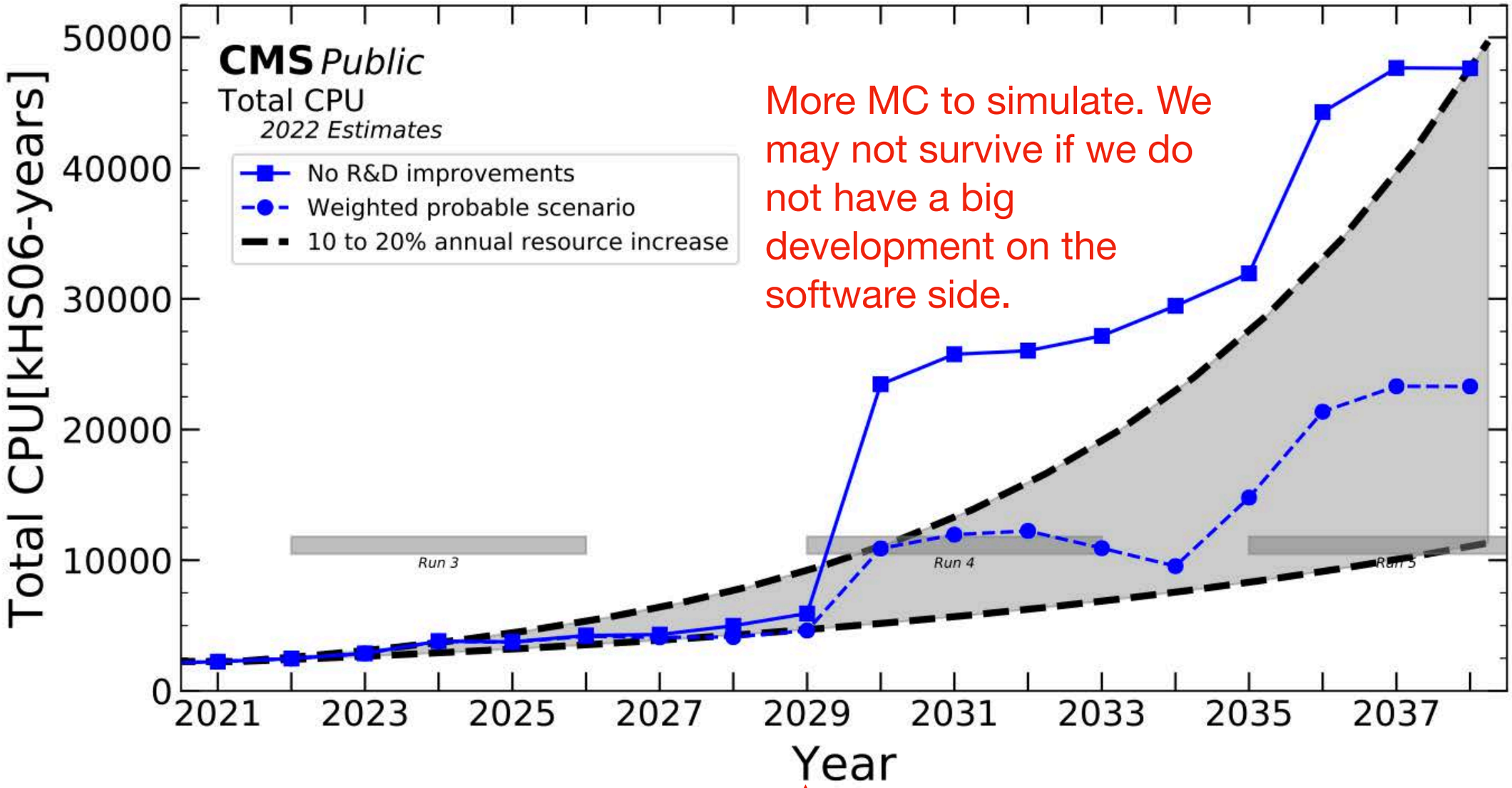
18 November 2023



What we are doing at CMS:

- Coordinate Phase-2 software: coordinate all detector groups, triggers and physics on dev plan, and release version of software used each year for Phase-2 study
- Pilot new method of very high statistics simulation using AI/ML

High luminosity LHC starts

CMS Phase-2 Detector with new sub-detectors

- Minimum Ionizing Particles Timing Detector (MIP Timing Detector; MTD)
- High Granularity CALorimeter (HGCAL)

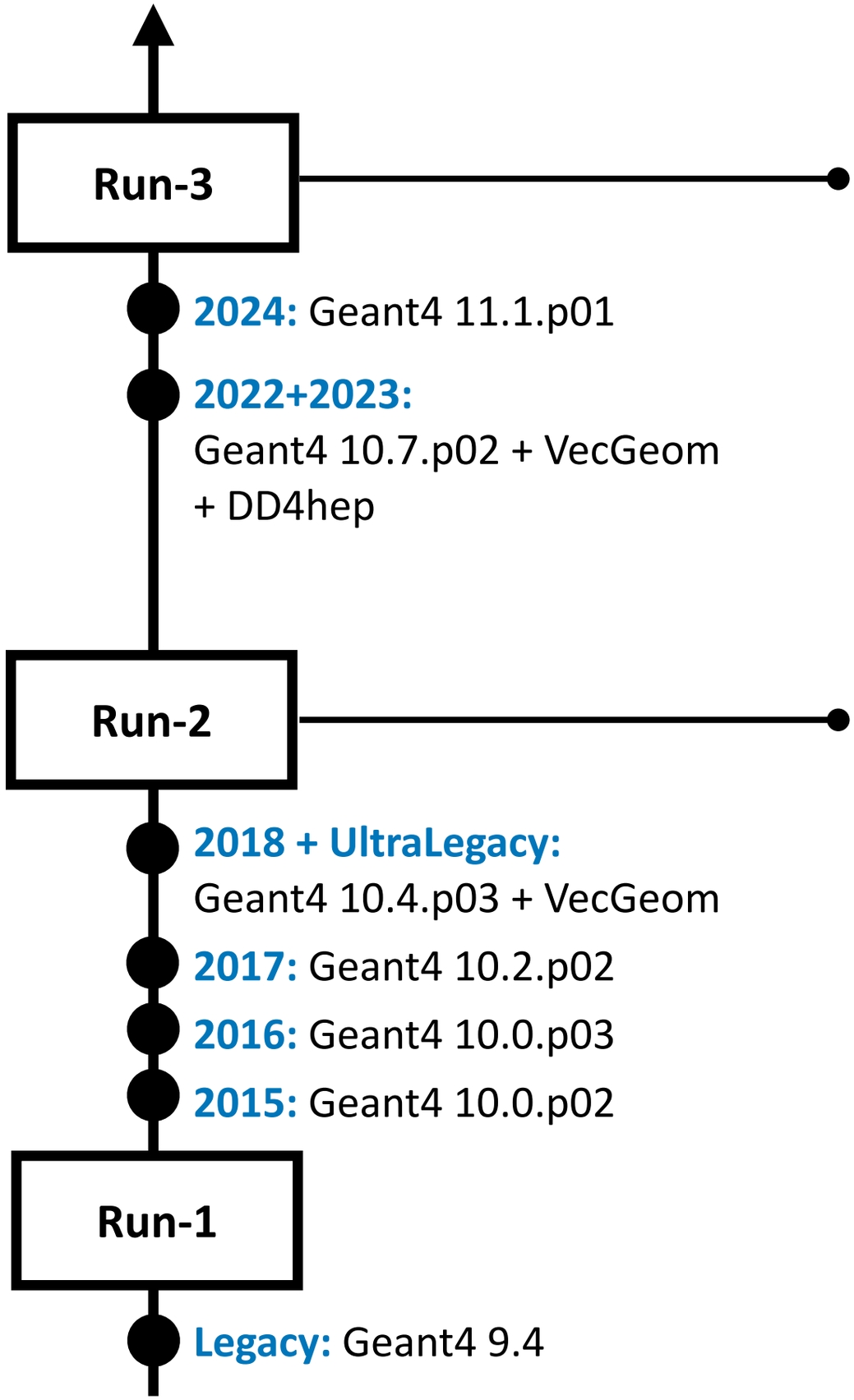
CMS Simulation Performance

- **Key success for CMS to speed up the simulation**
  - Using optimal compliers
  - Using most recent version of Geant4
- **Several optimizations have been introduced to Geant4-CMSSW configuration**
  - Simulation production for CMS Run-2 is significantly faster than the Geant4 default with FTFP_BERT
    - EMM: configuration of EM physics specific for CMS since 2017. Configuration different for crystal and sampling calorimeters like HCAL or HGCal.
  - For Run-3 2022-2023, 8% faster due to the Geant4 10.7.p02
  - *Expect performance improvement with Geant4 11.1.p01*

Run-2 simulation performance

Configuration	Relative CPU usage	
	MinBias	TTbar
No optimizations	1.00	1.00
Static library	0.95	0.93
Production cuts	0.93	0.97
Tracking cut	0.69	0.88
Time cut	0.95	0.97
Shower library	0.60	0.74
Russian roulette	0.75	0.71
FTFP_BERT_EMM	0.87	0.83
All optimizations	0.21	0.29

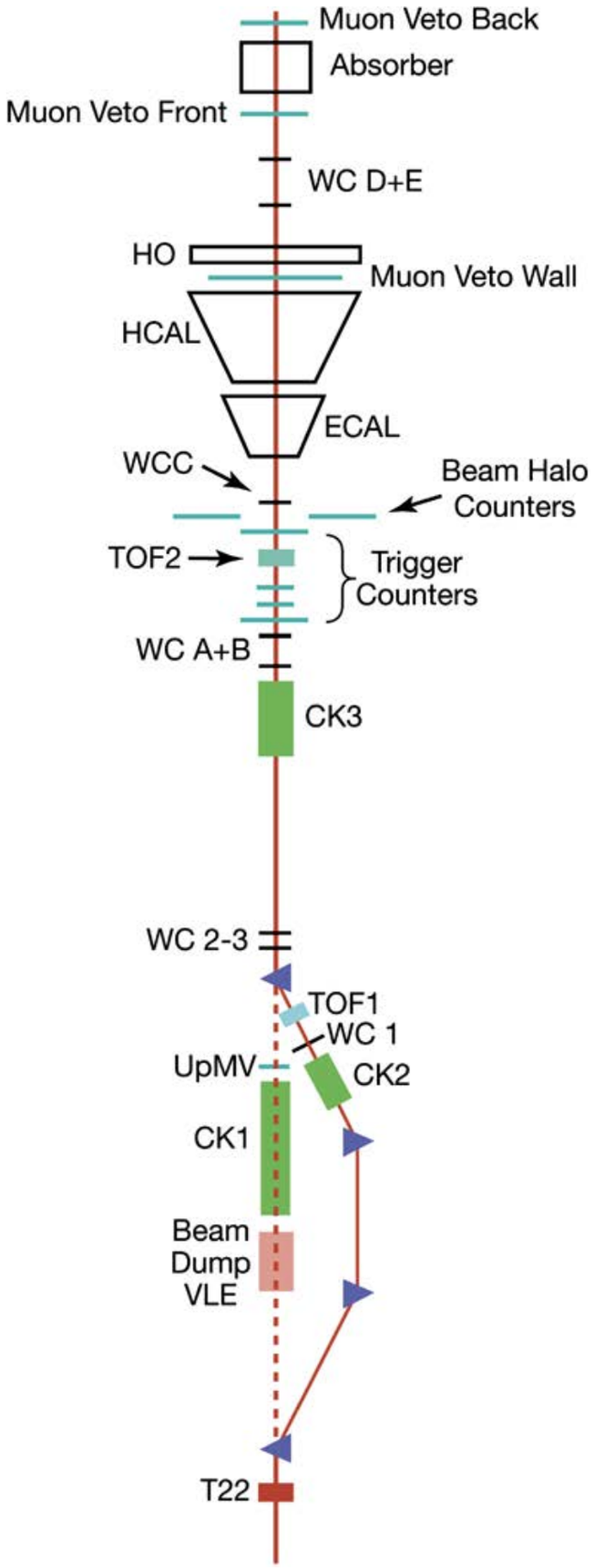
Geant4 versions with CMSSW



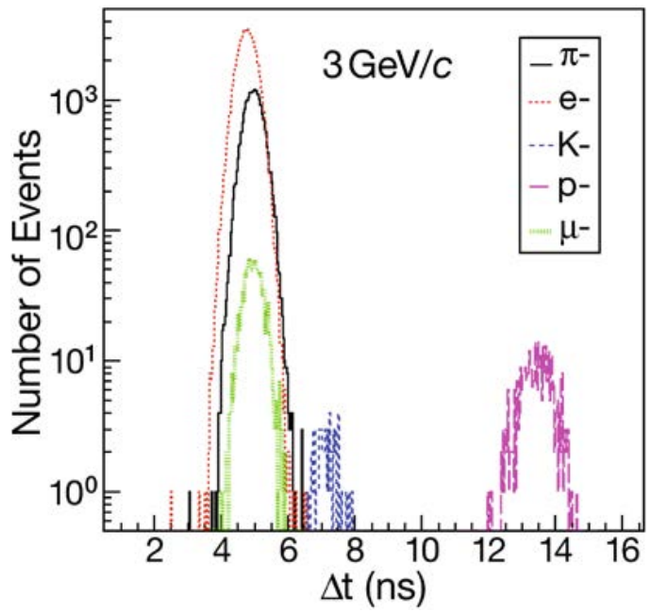
- **CMSSW_13_3 (or higher) for Run-3 2024**
  - New Geant4 11.1 (to be used first for Phase-2 simulation in mid 2023)
- **CMSSW_13_0 for Run-3 2023**
  - Gamma general process
  - Link Time Optimization (LTO) build
- **CMSSW_12_4 for Run-3 2022**
  - DD4hep geometry description

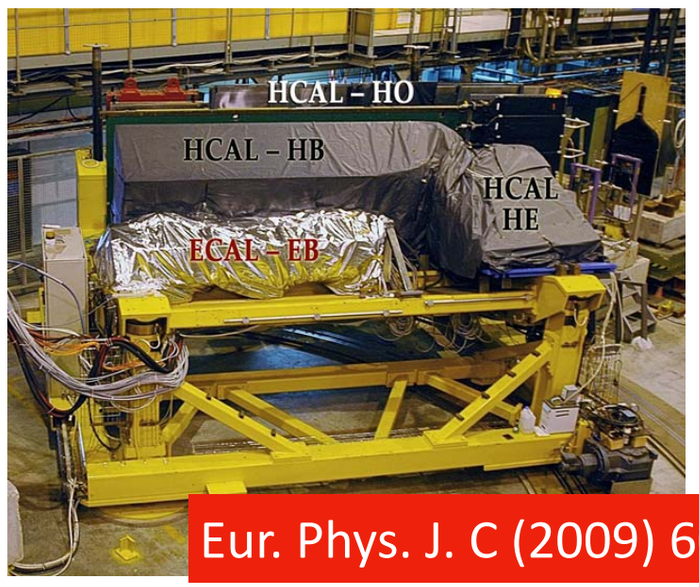
- **CMS Full simulation for Run-2**
  - Updated geometries for each year
  - Multithread mode in production since 2017
  - Configuration for physics:
    - FTFP_BERT_EMM
    - Russian roulette method
    - HF shower library

Migration of Geant4 under CMSSW



- **Software performance**
- **2006 test beam with CMS calorimeter prototypes**
  (beams of different types and different energies)





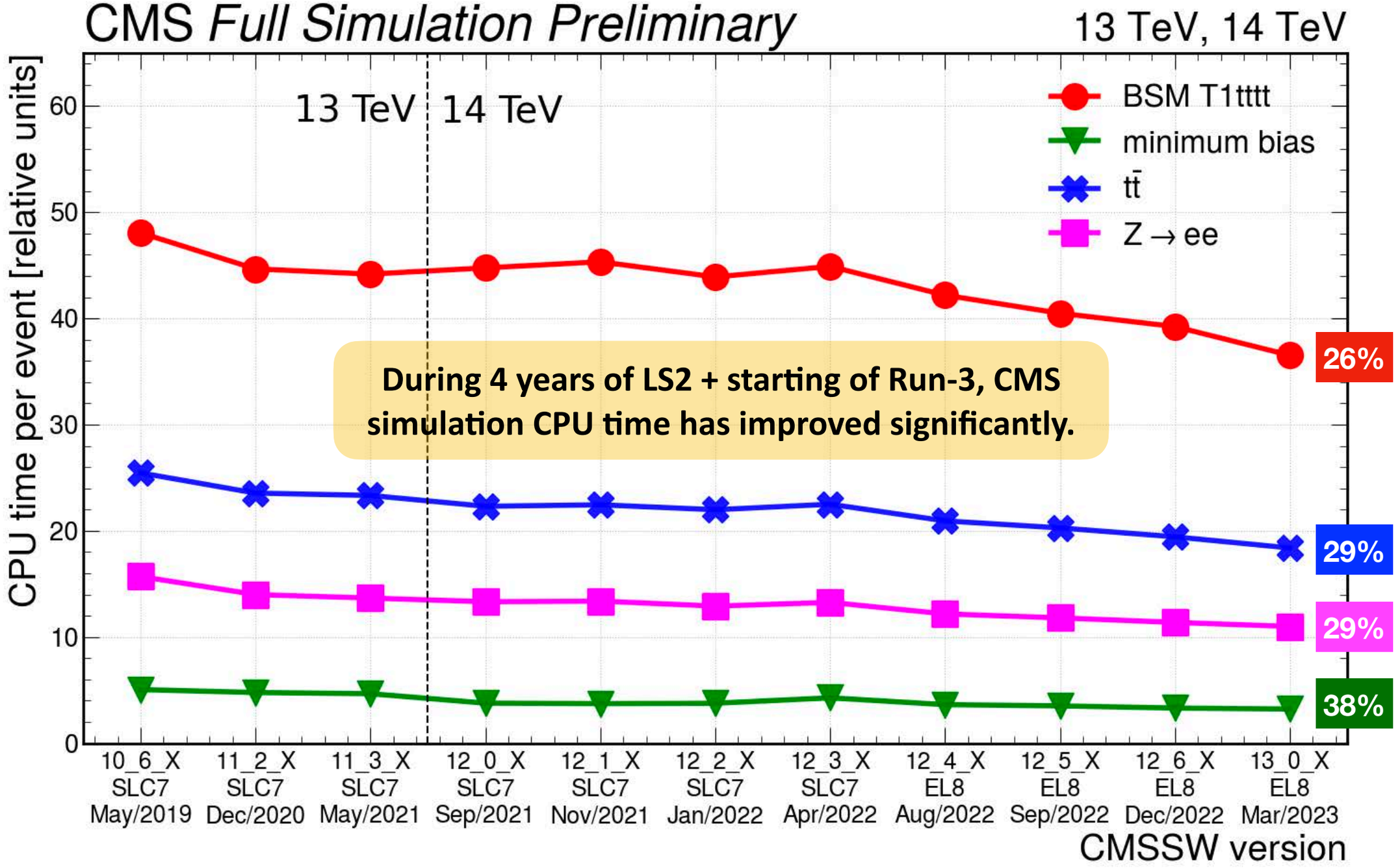
Eur. Phys. J. C (2009) 60: 359–373

- **Collision data from the CMS experiment** utilizing zero bias or minimum bias triggers from low luminosity runs

J. Phys.: Conf. Ser. 898 042005

- **Data-MC comparison:** Validation campaigns organized centrally, participation from detector performance and physics object groups.
  - **Run-3 2022** with Geant4 10.7.p02
  - **Run-2 Ultra-Legacy** with Geant4 10.4.p03

Full Simulation CPU time performance



During 4 years of LS2 + starting of Run-3, CMS simulation CPU time has improved significantly.

Historical trends of the CMS detector Full Simulation CPU time performance of Run-2 (with 13 TeV MC) and Run-3 (14 TeV MC).

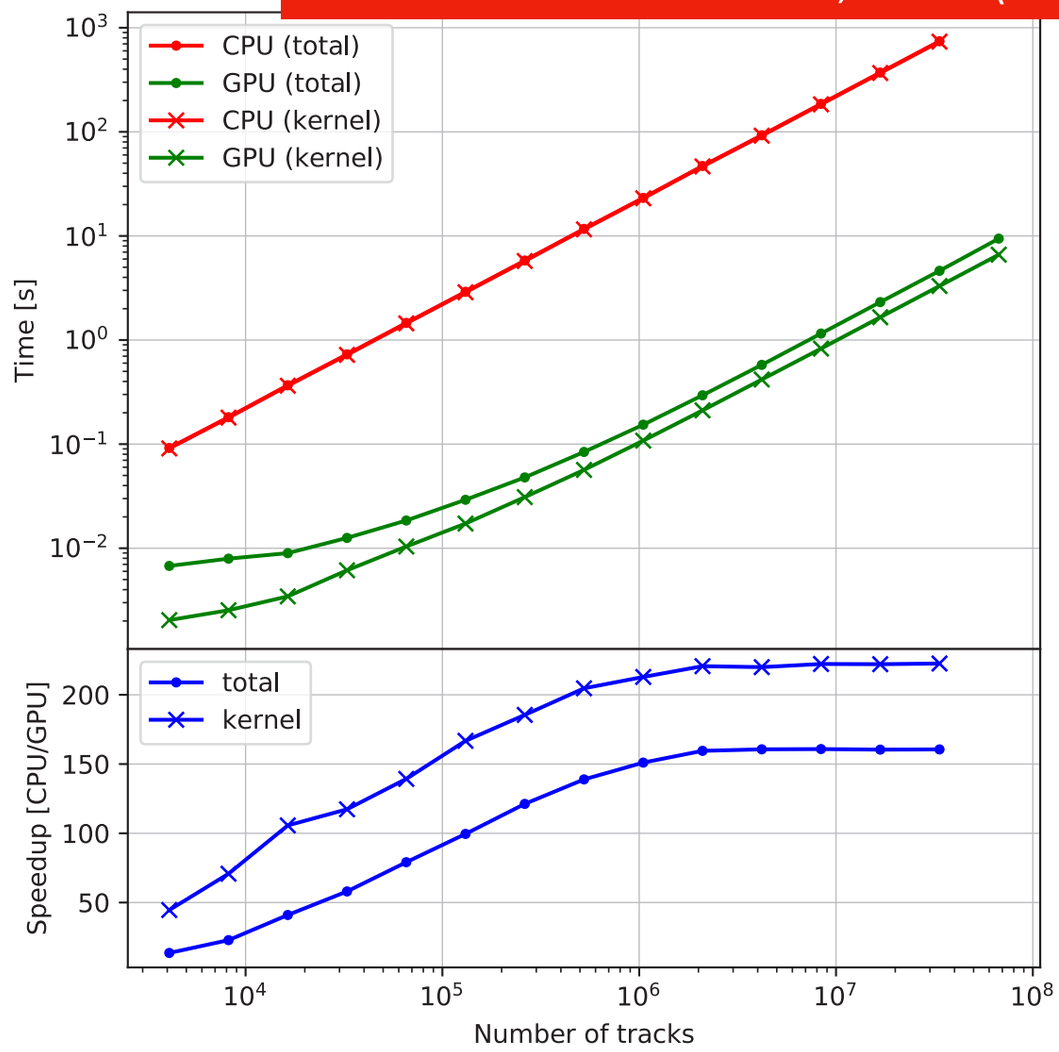
Looking forward for CMS Phase-2 simulation

- Migration to **CMS Phase-2 DD4hep geometry**

- New approaches for EM physics, to speed up the simulation without compromise of physics.
  - **G4TransportationWithMsc**
  - **Custom tracking manager**
    - Simplified e-gamma transport in Geant4
  - **G4HepEm external library**
    - Focus on the EM shower generation
    - Gateway for GPU usage for EM physics
    - https://github.com/mnovak42/g4hepem
    - https://g4hepem.readthedocs.io/en/latest/

- Follow R&D for GPU usage
  - **Accelerated demonstrator of electromagnetic Particle Transport (AdePT)**
    - https://github.com/apt-sim/AdePT (see CHEP2023 talks: 66, 163)
  - **Celeritas** (to implement HEP detector physics on GPU accelerator, targeting for HL-LHC)
    - https://github.com/celeritas-project/celeritas

EPJ Web of Conferences 251, 03030 (2021)



Performance comparison of the CPU (Intel Cascade Lake Xeon 2.3 GHz) and original GPU (Nvidia Tesla V100, CUDA 10.1) versions of the Celeritas code.

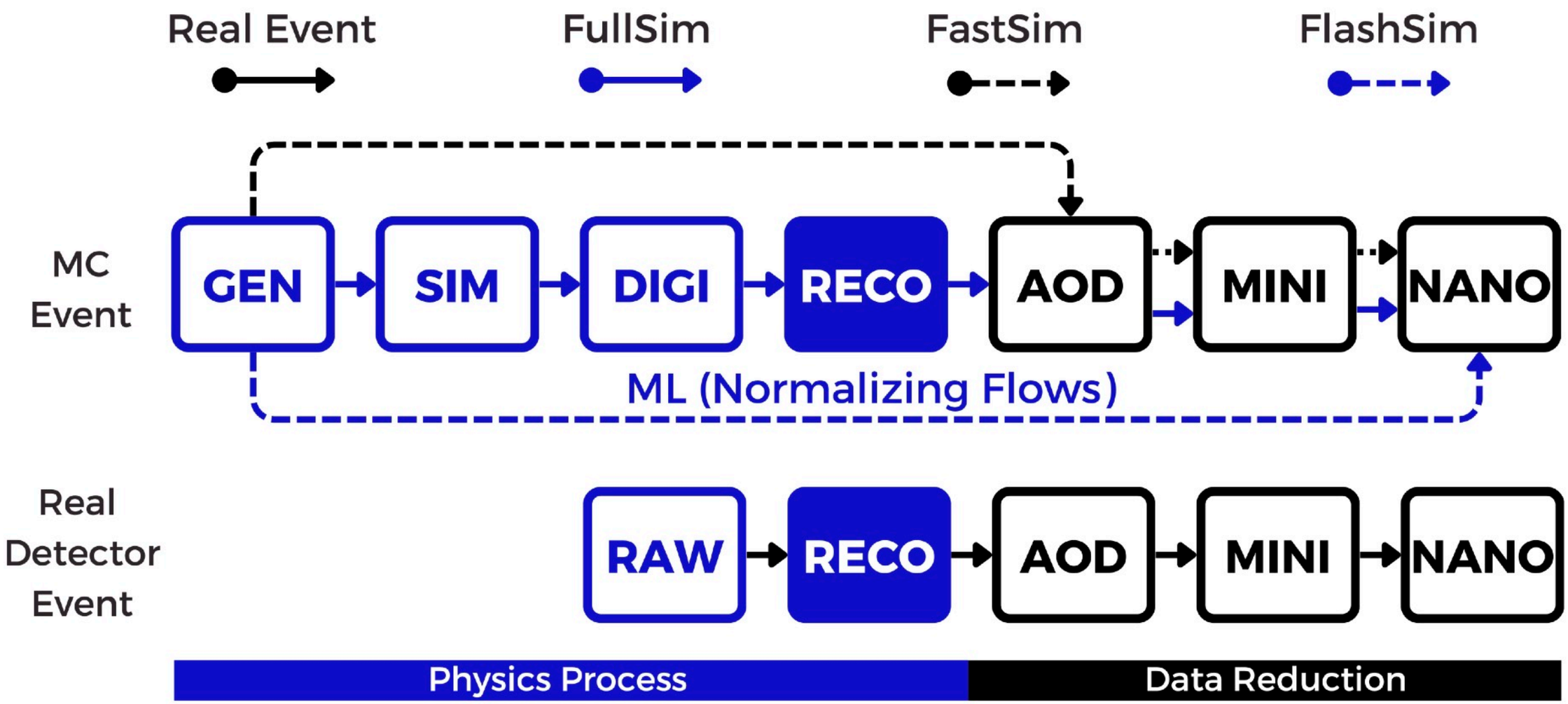
Thammachath (CU)
Senior project on Flash Simulation of Tau object

FlashSim-Tau

A Deep Learning Approach to the Problem of Tau Simulation

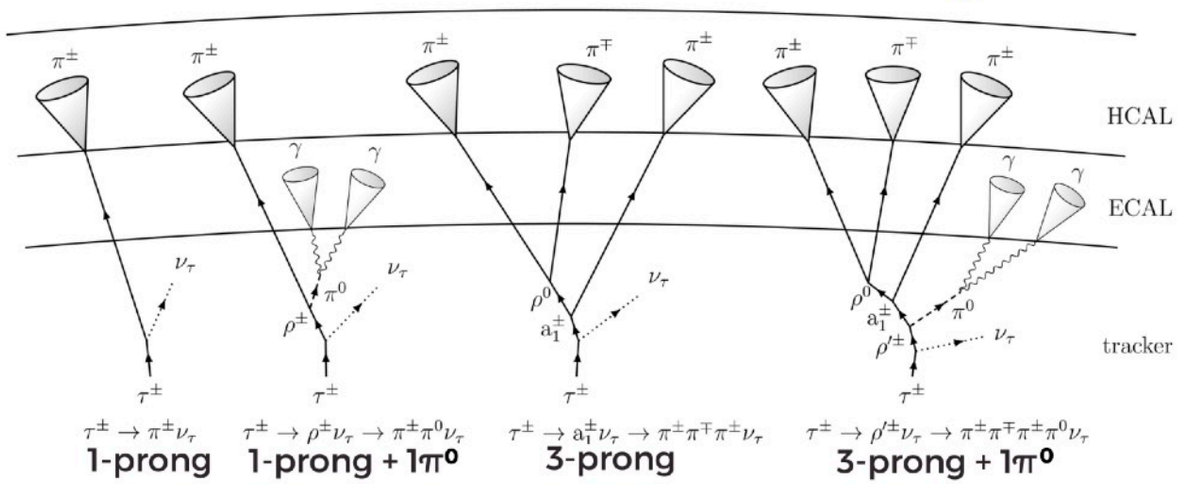
by Thammachath Sookpinij
Department of Physics, Chulalongkorn University

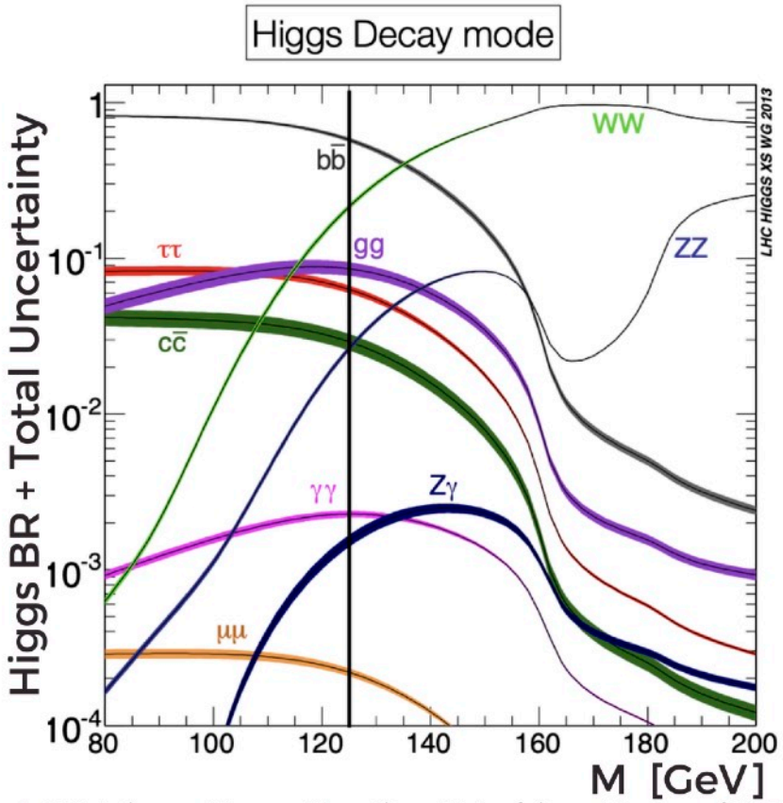
FlashSim



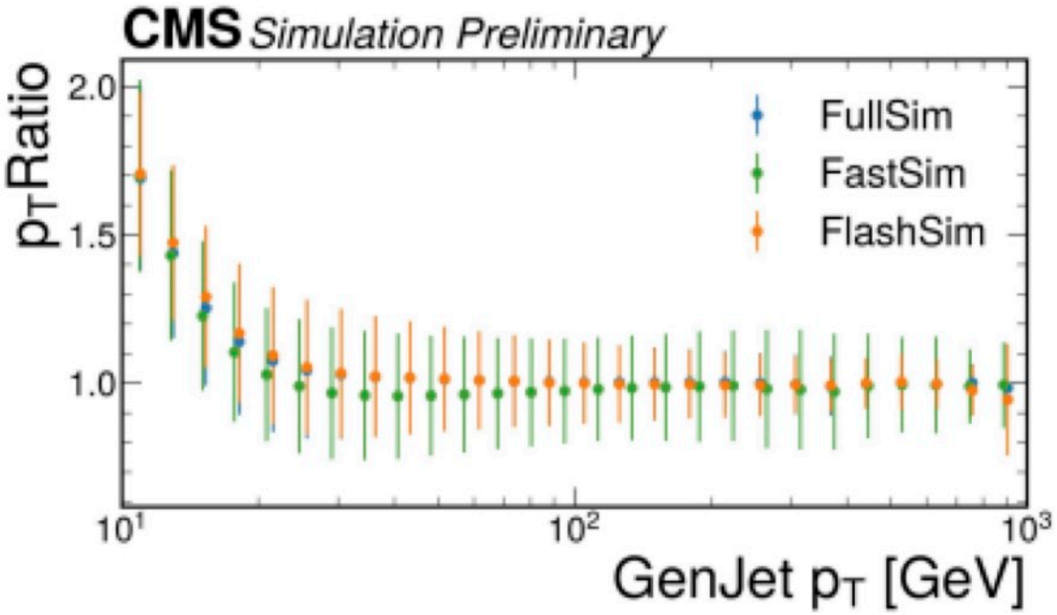
The comparation between the Flowchart of various CMS simulation and experiment

Hadronic Tau Decay





from The LHC Higgs Cross Section Working Group (2013) Handbook of LHC Higgs Cross Sections: 3. Higgs Properties, arXiv: 1207.1347

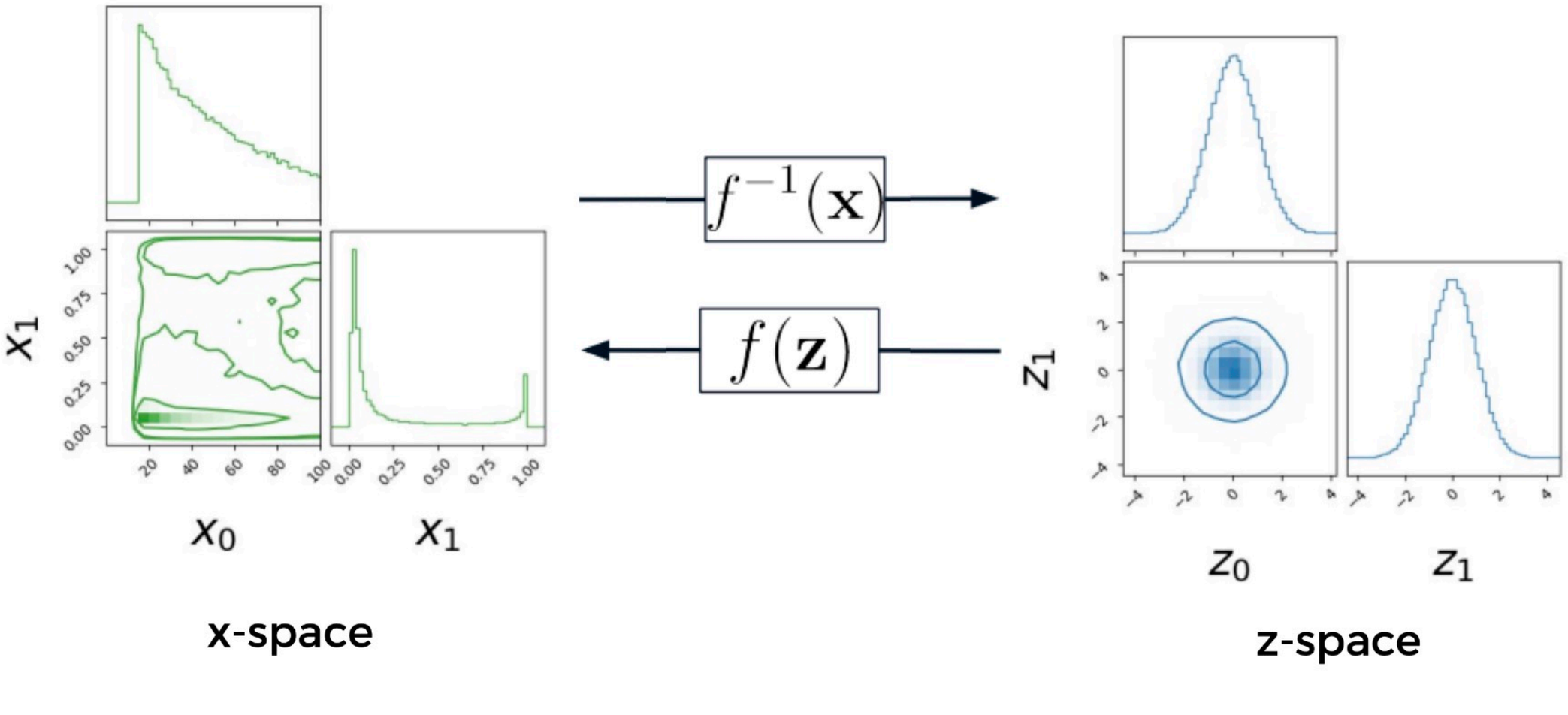


Full vs Fast vs Flash

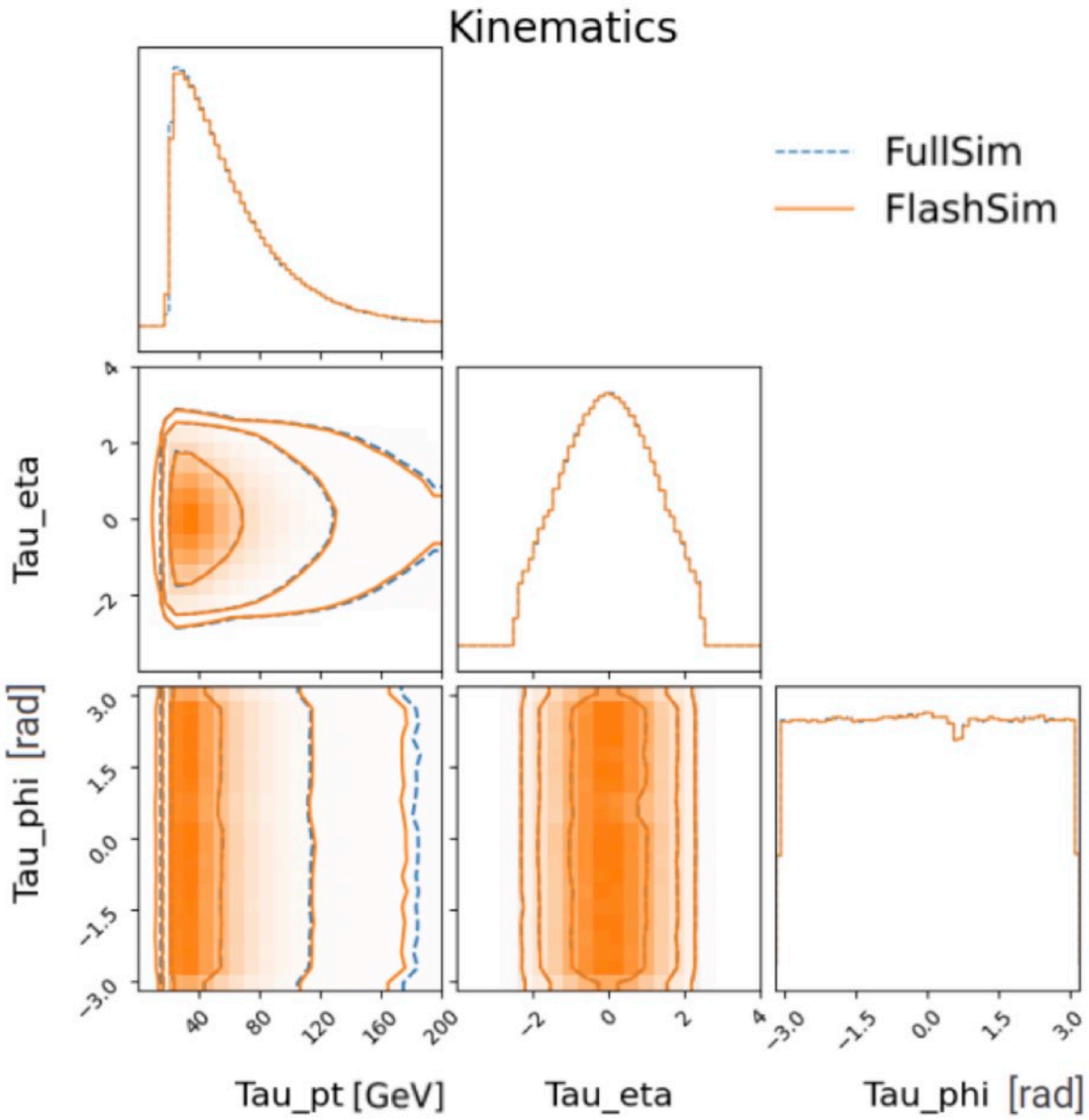
tranverse momentum Ratio
of Reco Jet and GenJet

from F. Vaselli, A. Rizzi, F. Cattafesta, G. Cicconofriand on behalf of the CMS Collaboration,"FlashSim prototype: an end-to-end fast simulation using Normalizing Flow", 2022

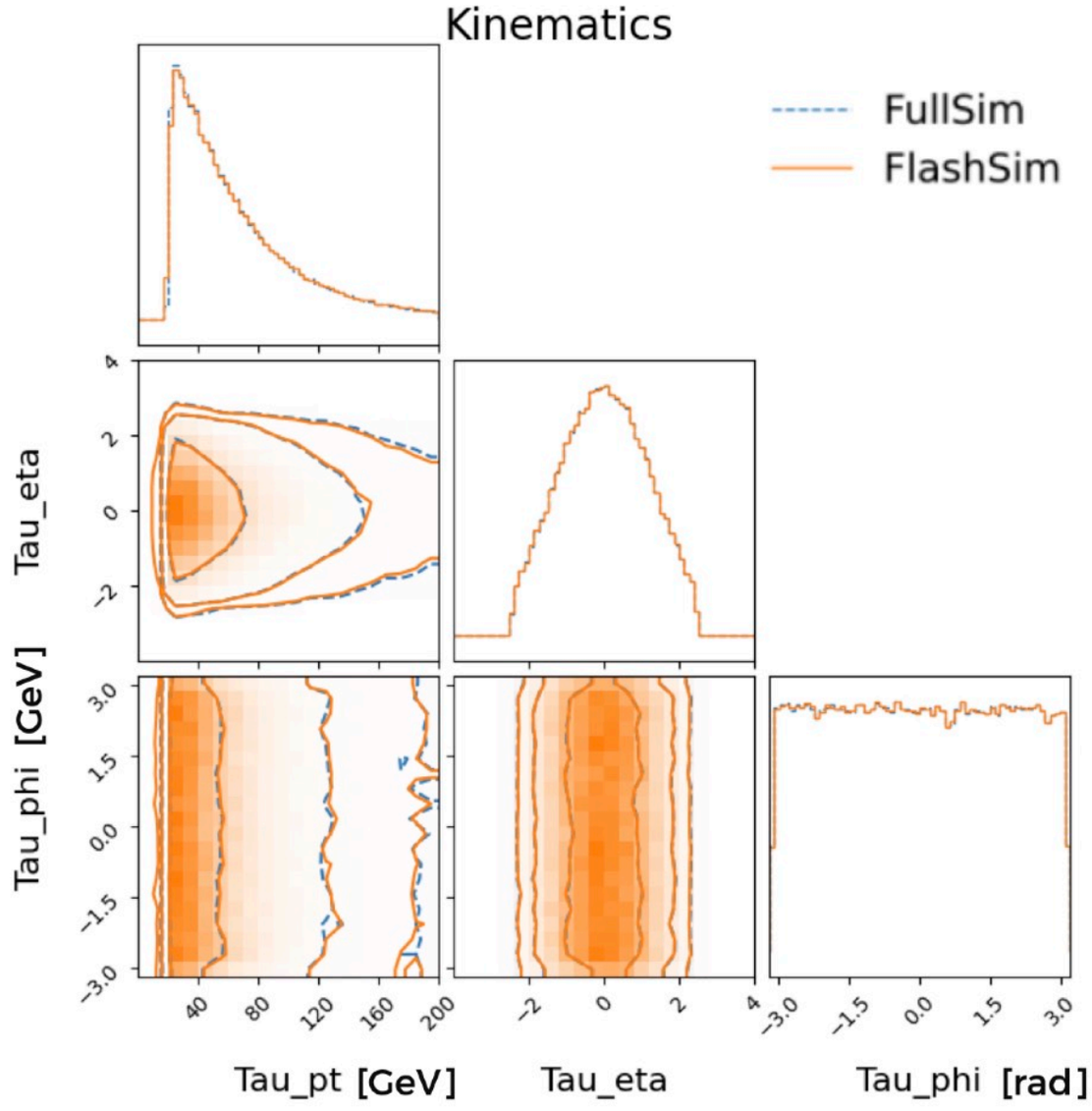
Normalizing Flows



Train and test with TTbar



Test with TTH



Next step: Integrate the model to CMSSW, complete missing physics objects
Co-effort between CERN, INFN (PISA), and CU

Looking for more opportunities for Thai

Help for career development and job opportunities for graduates and young physicists, engineers

- Thai computer engineers at CERN and Fermilab (US): strong grasp of programming languages, secure coding, and software and hardware technologies. ***This is one of our success stories at CERN.***
- Continue project after CERN summer school

Purinut (CU)
Summer Student 2023
Continue on FCC accelerator study

Vichayanun (CU)
Summer Student 2015
Ph.D. thesis on CMS topic
(Just done)

- Expanding the collaboration with CERN IdeaSquare. The first step to to go for CERN knowledge transfer, design thinking.

Thanayut (KU)
Analysis support, CMS
(Ongoing)

Chan-anan (KU)
Site operators, Fermilab
(Ongoing)

Peerut (CU)
Summer Student 2015
Data Quality Monitoring
(Done)

Sarun (CU), CERN
Summer Student 2020
Site operation, CMS
(Ongoing)

Seksun (MSU)
Workshop organized by CERN IdeaSquare