Simulating the Forward Calorimeter for Luminosity Measurements in CMS

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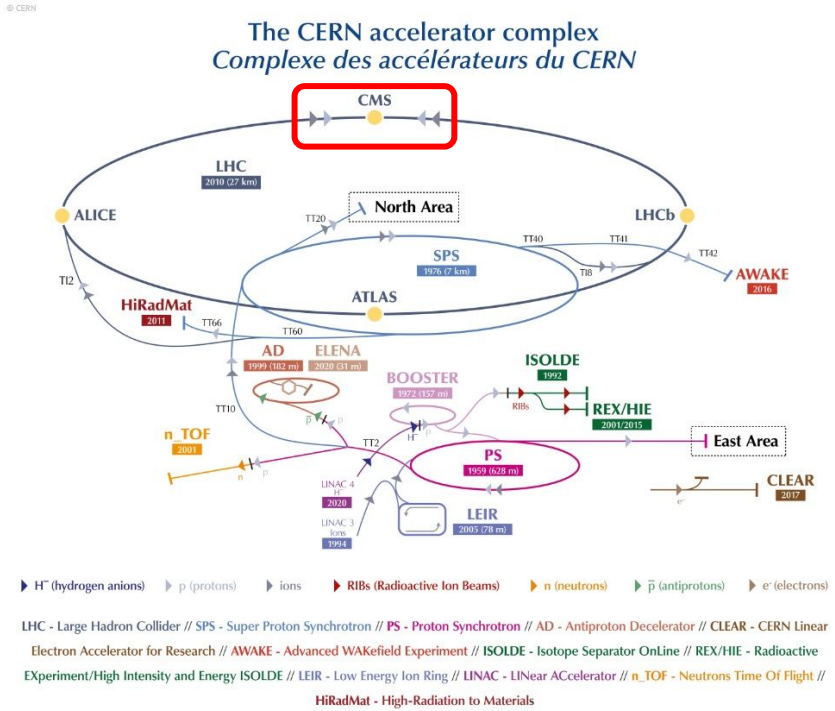
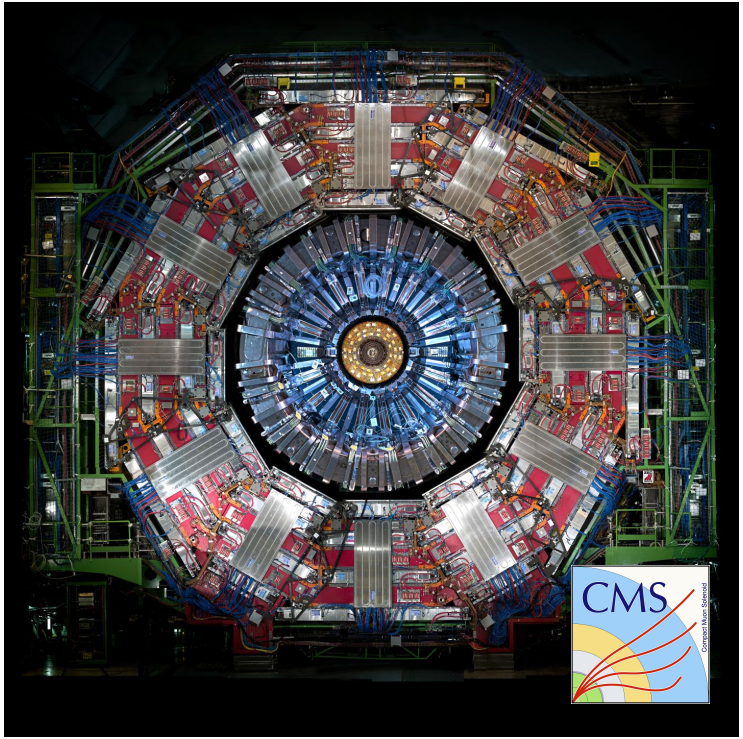
Outline

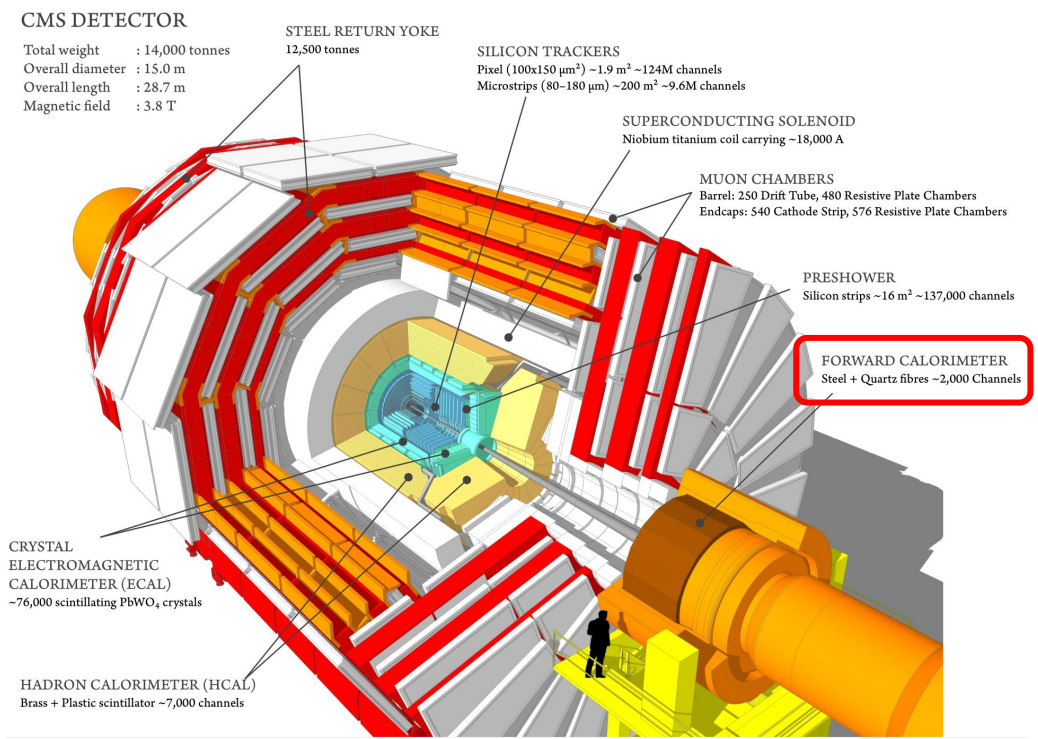
- Context review: the LHC & the CMS experiment
- Particle *collisions* in theory & experiments
- What is luminosity?
- How is luminosity measured?
- Simulating the HF for luminosity measurements in CMS

Context review: the LHC & the CMS experiment

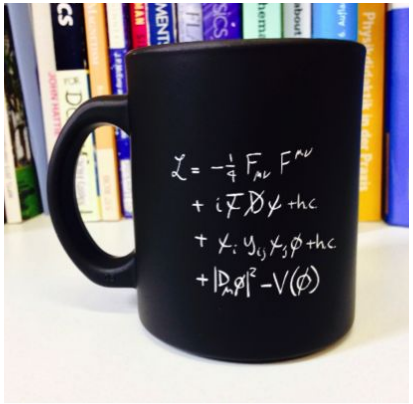


Context review: the LHC & the CMS experiment



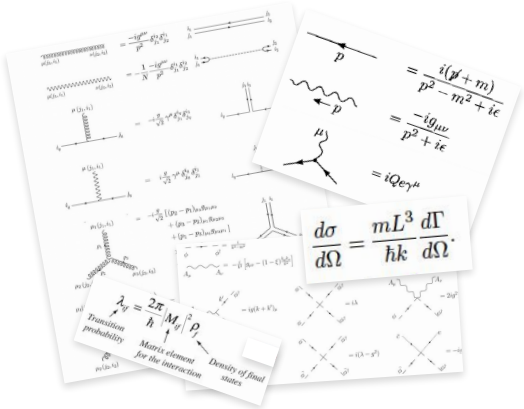


Particle *collisions* in theory & experiments



A lagrangian determined by the principles of the theory of special relativity, quantum field theory and local gauge invariance.

Feynman diagrams for scatterings and decays representing the possible interactions and dynamics of matter particles.



Predictions of cross sections and decay (production) rates are the main **observable quantities in experiments**.

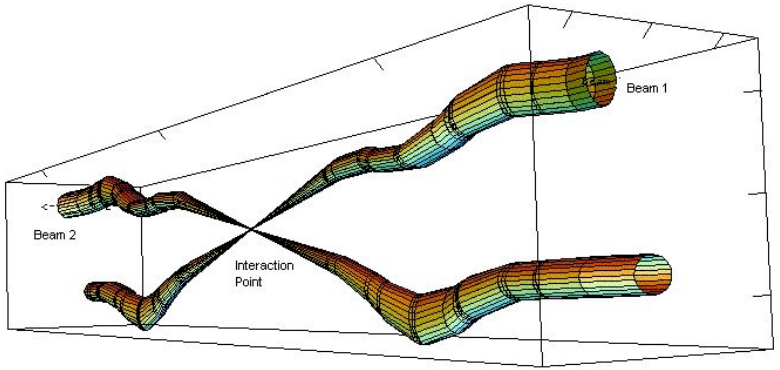
Particle *collisions* in theory & experiments

pp collision

(qq, gg or qg)

~10^9 protons per bunch

paquetes de protones



Relative beam sizes around IP1 (Atlas) in collision

trenes

~10^3 bunches circulating in the LHC

Bunch crossing frequency of 40 MHz

~50 pp collisions per bunch crossing

~10^9 collisions per second

???

What is luminosity?

A measure of how tightly packed the particles are in the beams; it is directly related to the number of collisions in each BX.

Instantaneous luminosity

Rate at which particles are brought together to collide.

$$\mathcal{L}(t) = \frac{\gamma n_b N_p^2 f}{4\pi\beta^* \epsilon_n}$$

$$\frac{dN}{dt} = \sigma \mathcal{L}(t)$$

Integrated luminosity

Measure of the accumulated number of collisions over time.

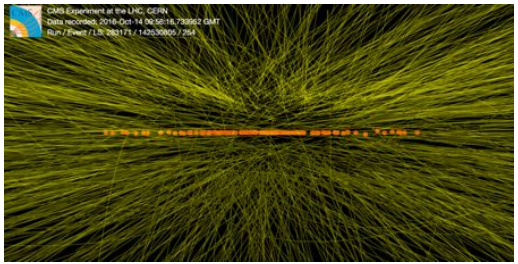
$$L = \int \mathcal{L}(t)\, dt$$

$$\sigma = \frac{N_{sel} - N_{bkg}}{L\, A\, \epsilon}$$

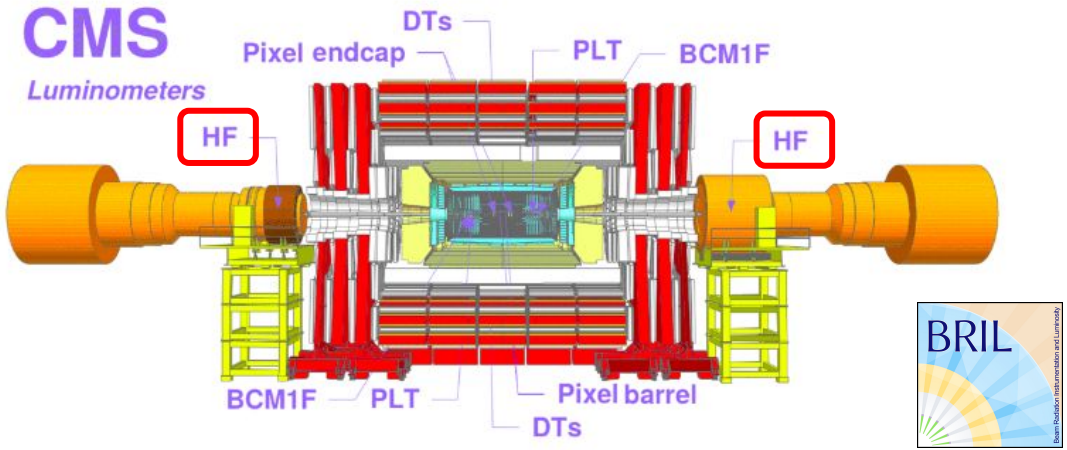
It is essential for:

- **Monitoring** beam conditions for optimization of LHC operations to produce the most collisions possible.
- **Optimization** of trigger rates and quality of the beams.
- **Protection** of the LHC machine and sensitive parts or sub-detectors of the experiments.
- Nearly any **physics** analysis that will be performed on the resulting data.

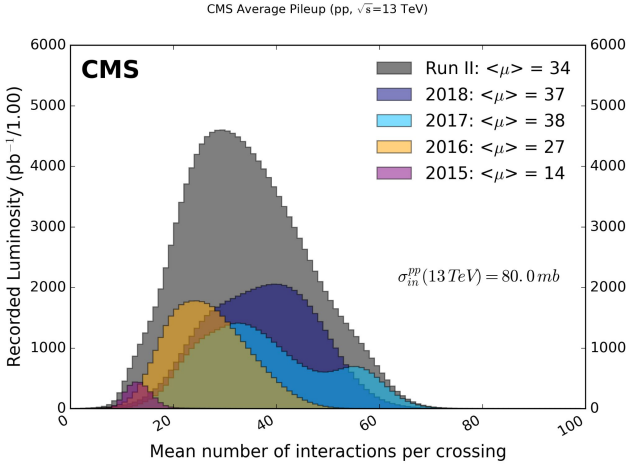
…but very tricky to determine experimentally.



How is luminosity measured?



BRIL: Beam Radiation, Instrumentation, and Luminosity

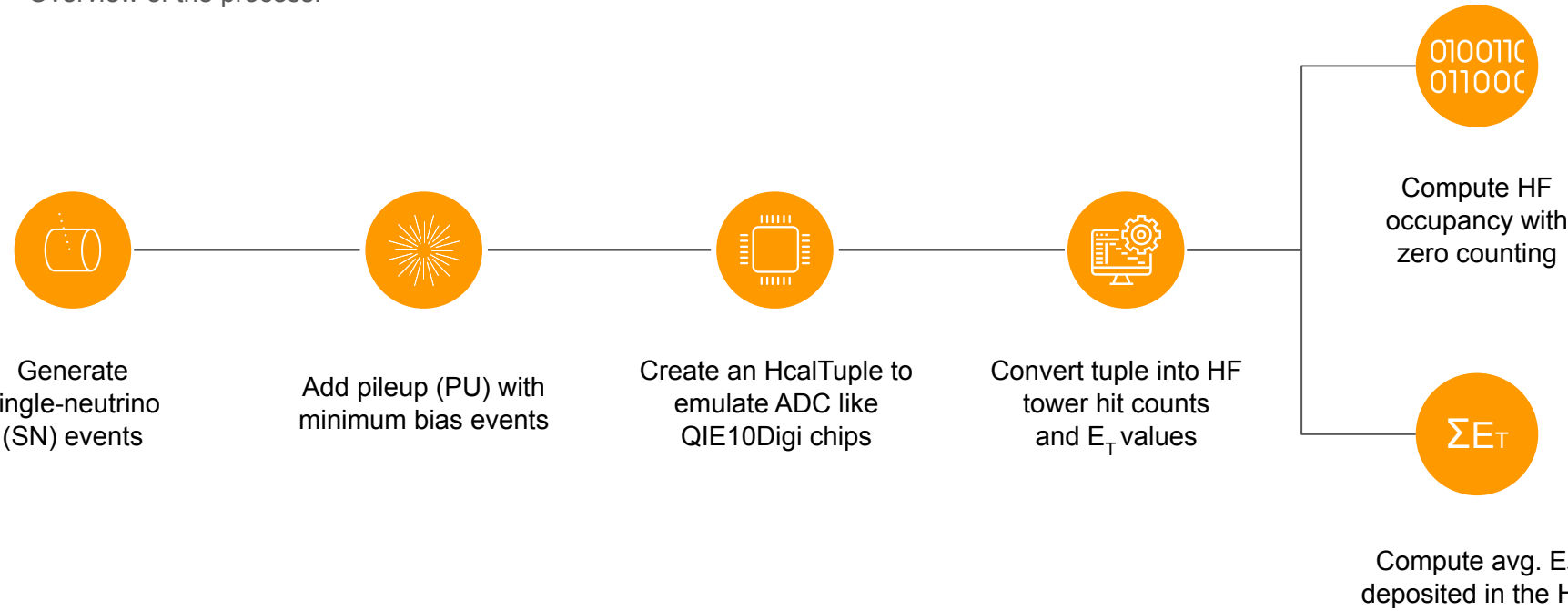


Pileup

- The HF can be used for luminosity measurements with two different methods: zero counting (HFOC) and measuring the total E_T deposited in the detector (HFET)

Simulating the HF for luminosity measurements in CMS

Overview of the process:



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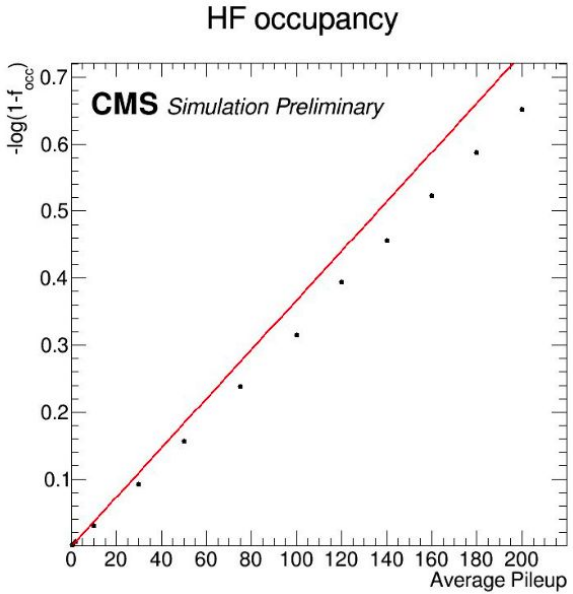
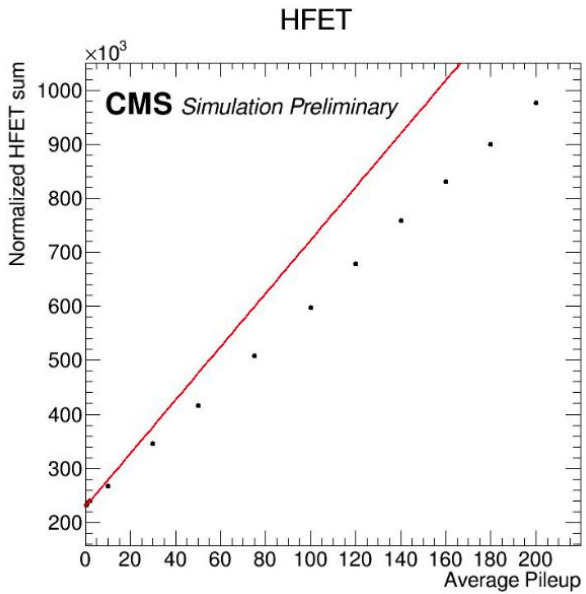
- Preliminary tryouts with low statistics.





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THANK YOU!! :P

References

- The Phase-2 Upgrade of the CMS Beam Radiation, Instrumentation and Luminosity Detectors. Technical Design Report. CERN, 2021.
- Luminosity measurement at CMS. BRIL Seminar. Andrés G. Delannoy, 2023.
- Luminosidad de alta precisión en el experimento CMS del LHC. Seminario de Física y Matemáticas, Universidad Iberoamericana Ciudad de México. Cristina Oropeza Barrera. 2022
- The installation of the BRIL luminometers: preparing for a bright run 3. Andrés G. Delannoy and Joanna Wanczyk, for the BRIL group. 2021 >>
- Planning for years of luminosity measurements with BRIL. Paul Lujan. 2021
- Illuminating! Counting LHC collisions with CMS. CMS collaboration. 2016
- A New Generation Of Charge Integrating ADC For The CMS HCAL Upgrade. Elliot Hughes >>