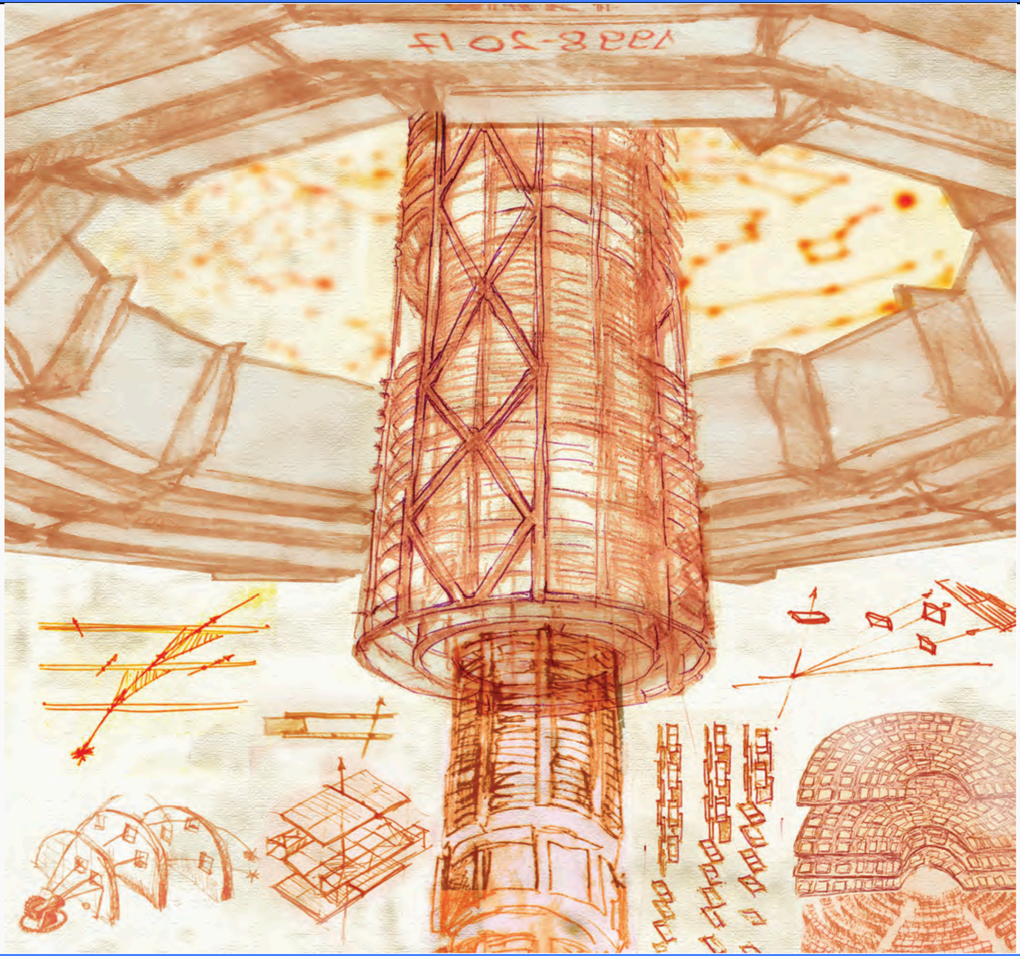
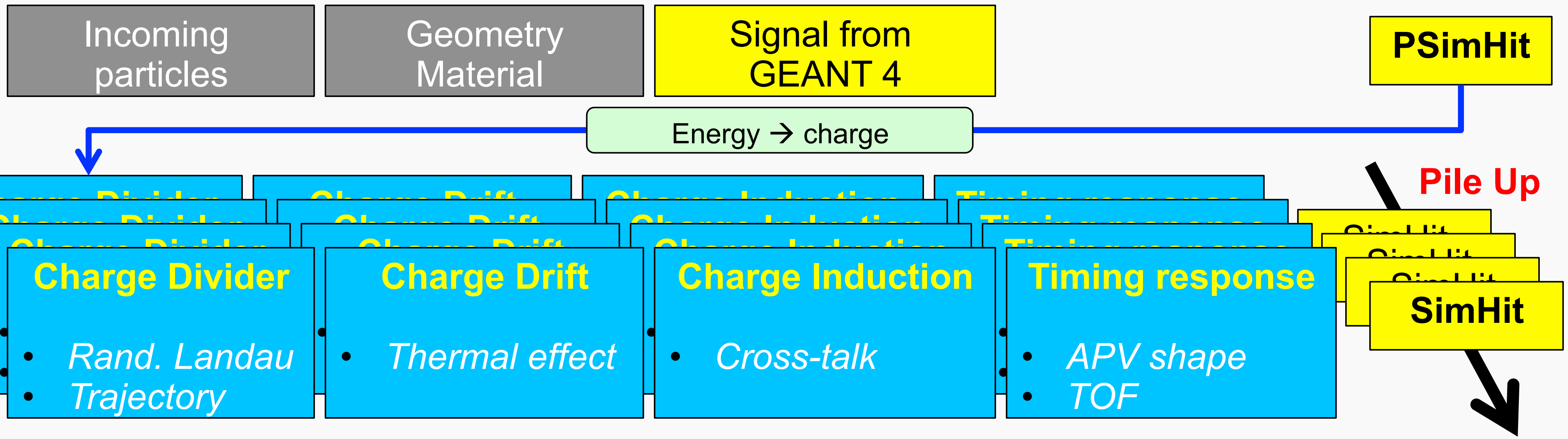
# Silicon Strip Sensor Simulation in the CMS Monte Carlo Framework



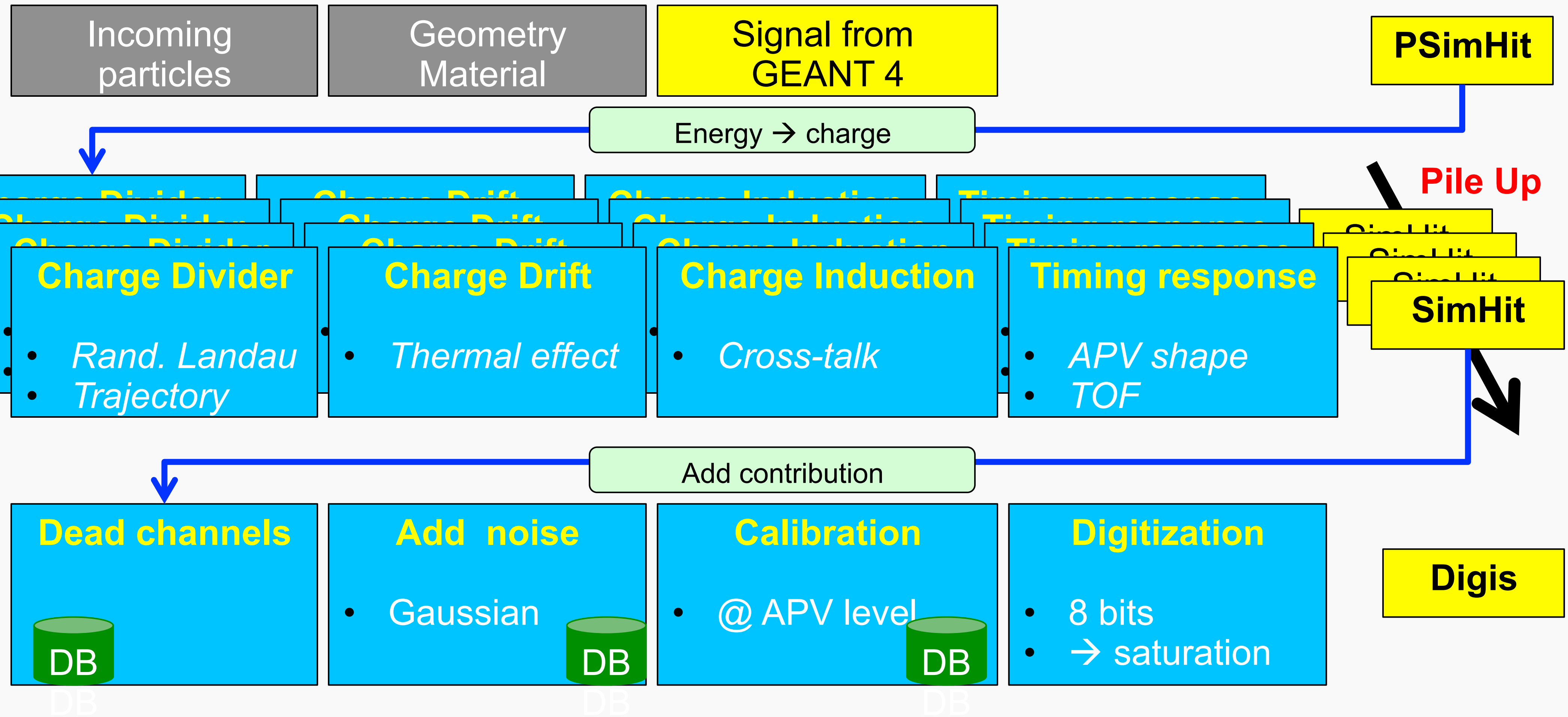
# Outline

- Overview of the CMS tracker simulation
- Overview of recent activities
- Cross-talk measurement
- Front-end electronic pulse shape
- S/N trend
- Dead time & inefficiencies
- Hit resolution

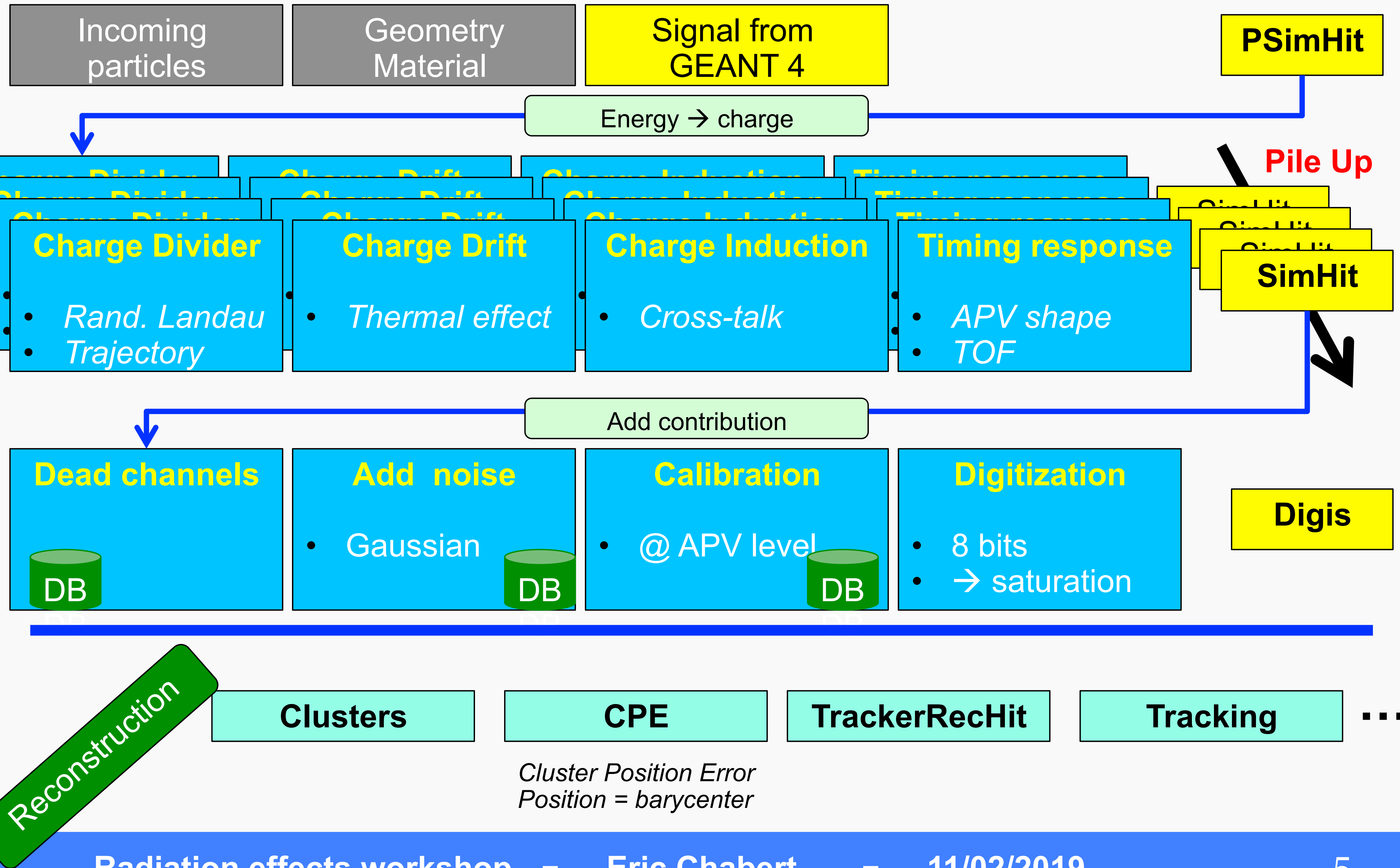
# Overview of the CMS strip simulation



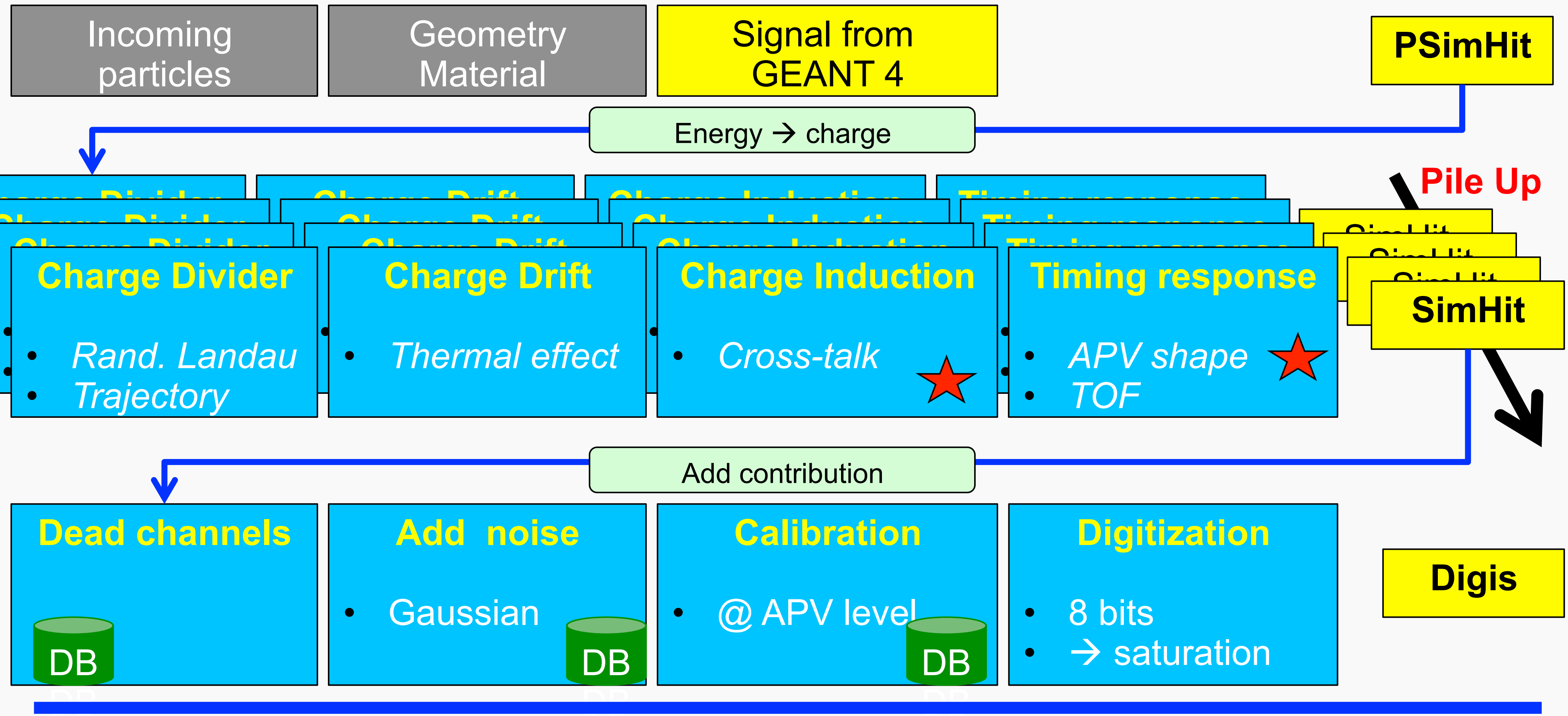
# Overview of the CMS strip simulation



# Overview of the CMS strip simulation



# Recent activities on the CMS strip simulation




DB Offline DB conditions have been updated in 2018

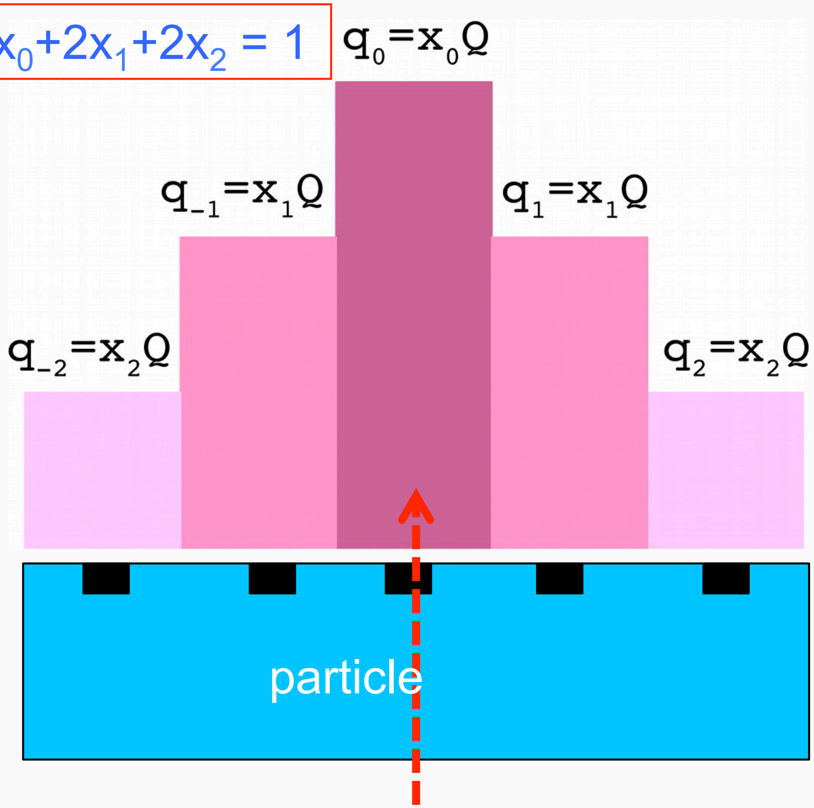
★ Cross-talk parameters have been updated
APV shape change under validation

# "Cross-talk" measurement

Mainly due to interstrip capacitive coupling, a cross-talk induces signals on strip neighbors to the one under which a particle went through

*Example of a « one strip » cluster :*

$x_0+2x_1+2x_2 = 1$

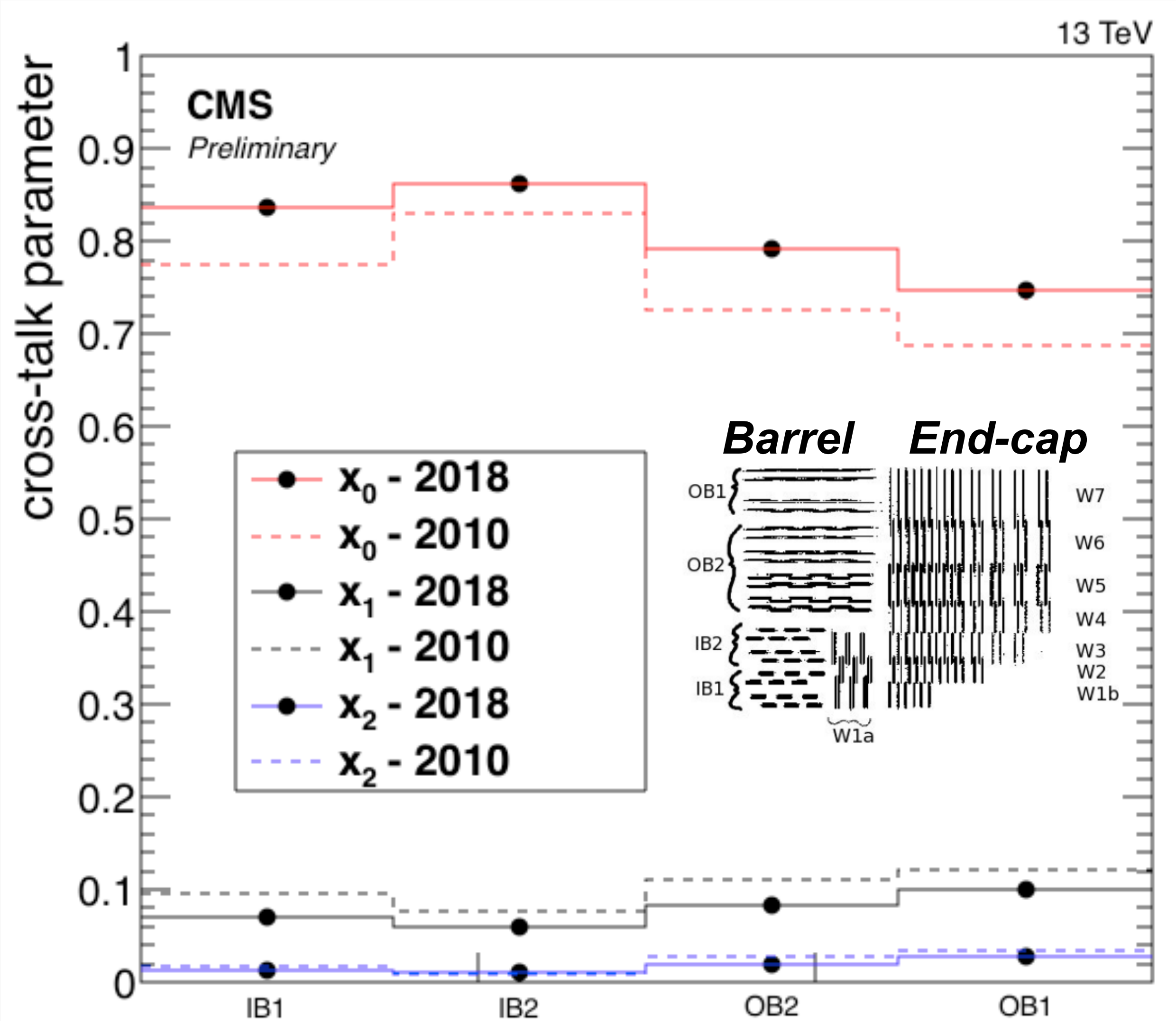



- **Measurements** obtained from cosmics data with 0 T using DAQ in Virgin Raw mode (no zero suppression)
  - → Lorentz Angle null
  - → Remove threshold bias
- **Methodology:**
  - Selection of tracks perpendicular to the sensor
  - Correction for timing delays
  - Fit of the leading strip charge and its neighbors.

$$\eta_i \equiv \frac{q_{\pm i}}{q_{seed}} = \frac{x_i}{(1-2x_1-2x_2)}$$

$$x_i = \frac{\eta_i}{1+2\eta_1+2\eta_2}$$

# “Cross-talk” measurement

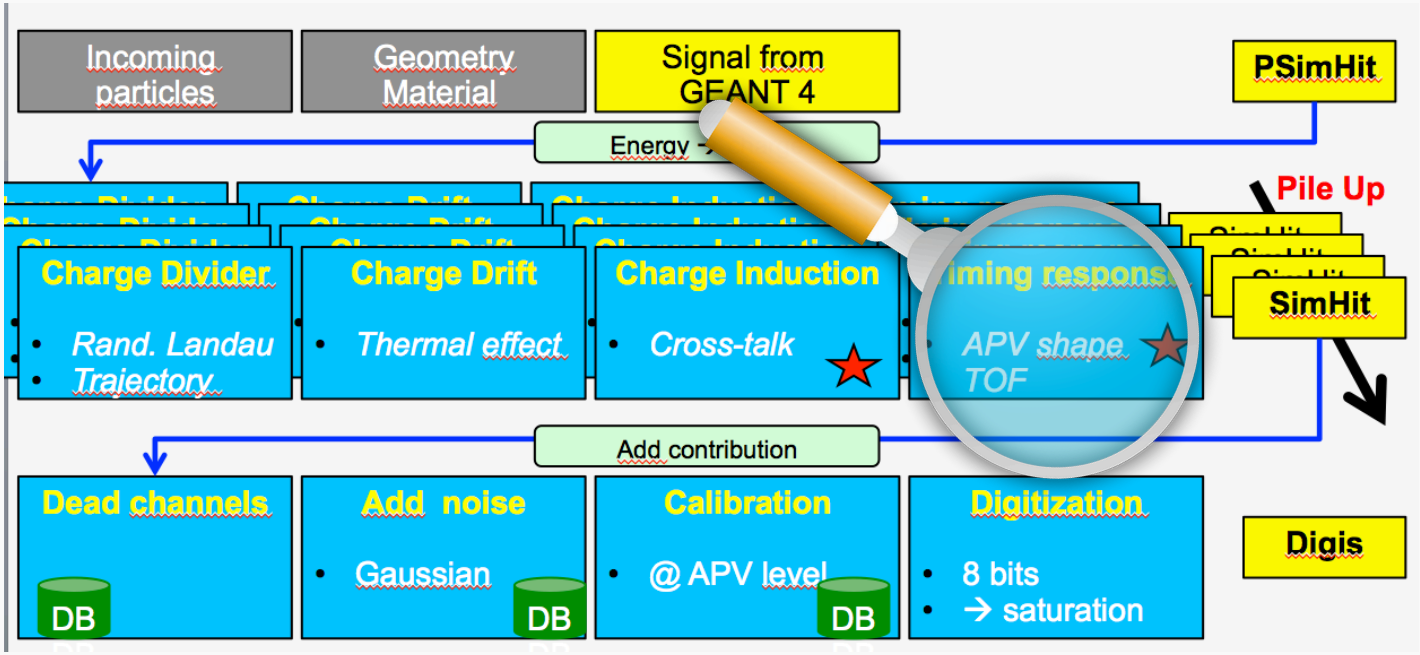



| thickness | 320 μm | 320 μm | 500 μm | 500 μm |
|---|---|---|---|---|
| pitch | 80 μm | 120 μm | 122 μm | 183 μm |

Radius

- One measurement done per sensor topology
- **Conclusion**: clusters narrower in 2018 than during Run I
  - → Less sharing
  - → Evolution of interstrip capacitance was expected due to radiation damage
- Cross-talk ranges from *15 to 30%* of the charge
- In our simulation, all physical effect inducing “charge sharing ”beyond the thermal diffusion are encapsulated in “cross-talk parameters”
- MC parameters have been updated to reflect the new measurement
- Improvement on data/MC agreement
- Measurement to be updated

# Front-end electronics pulse shape




The amplitude of the charge measured at a given bunch crossing in a FE channel depends on

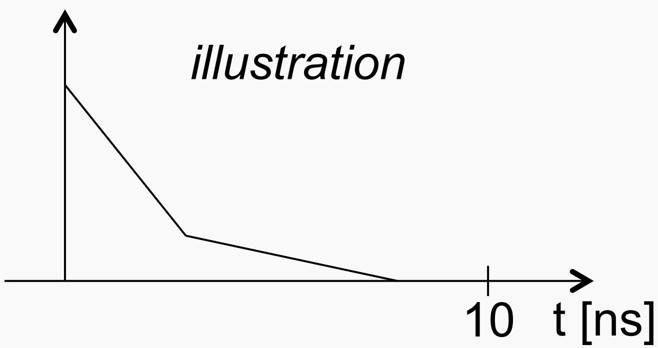
- The **time-of-flight** on the incoming particle
- The **OOT contributions** from other BX

→ To reflect this behaviour, it is required to inject the knowledge on the **timing response of the FE electronics**

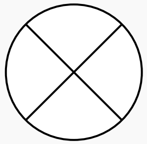
# Front-end electronics (APV) pulse shape

## Physical signal

→ Can be estimated through external dedicated program

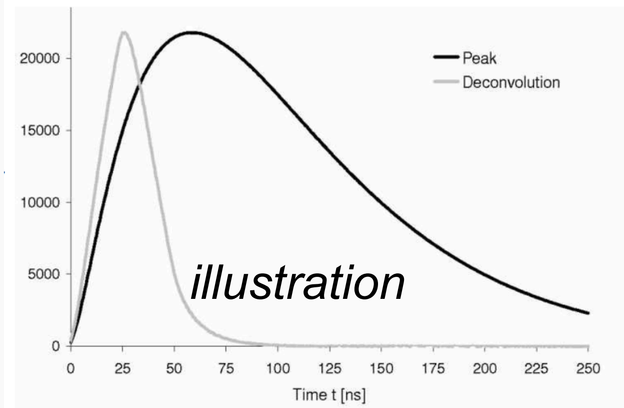



**convolution**



## Electronic response

→ Is measured with dedicated runs where a charge is locally injected on the FE chip



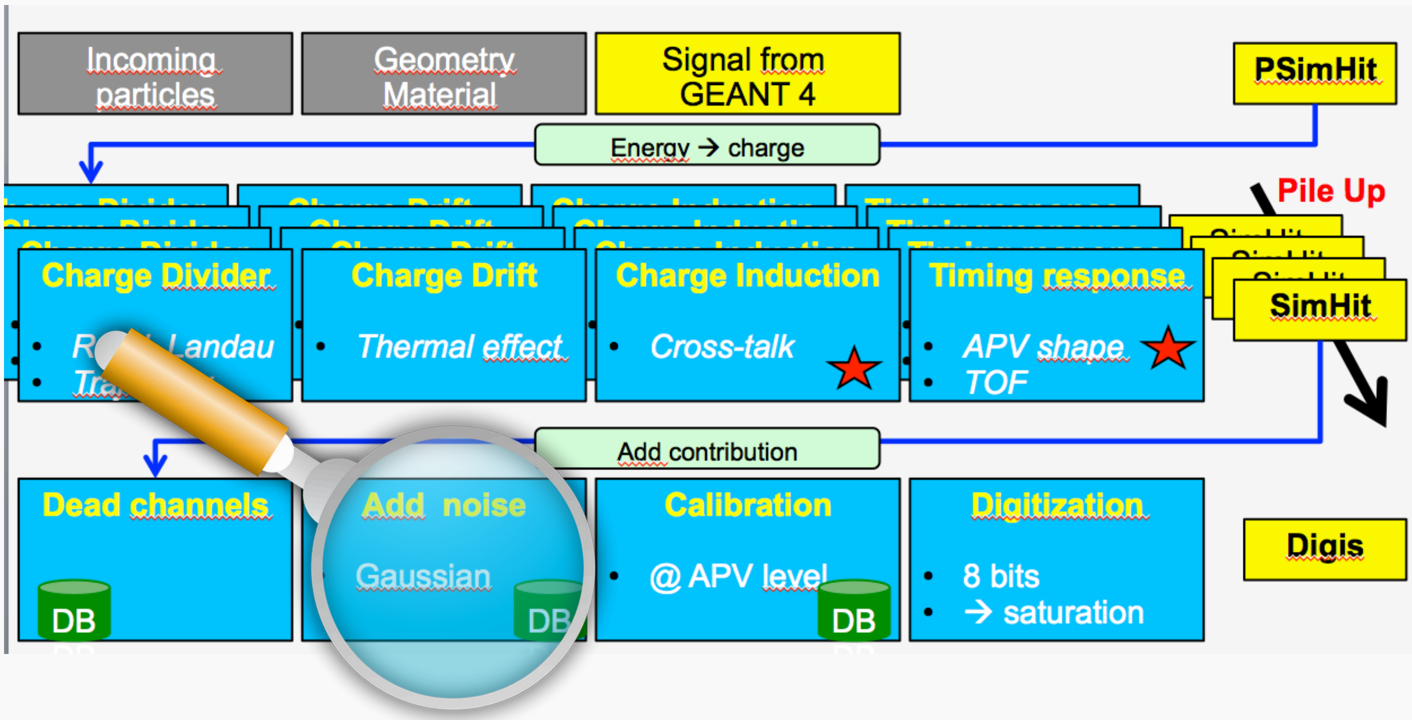

**Motivation for an update:**

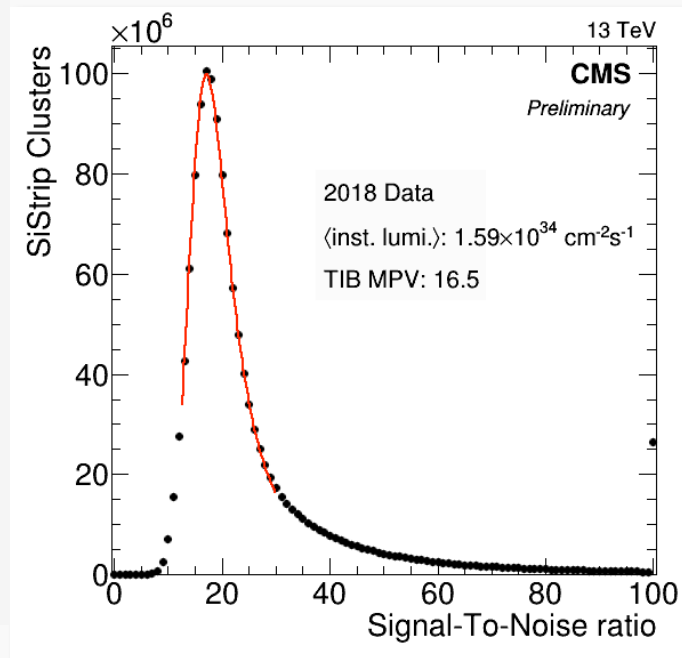
→ Use a more realistic physic signal

→ As the FE preamplifier parameters have been changed in 2016, the electronic response has been modified

- Tails of the cluster charge and cluster width distributions contributions are sensitive to the FE pulse shape description
- Required for a good modelling of the OOT contributions

# Evolution of S/N during Run II

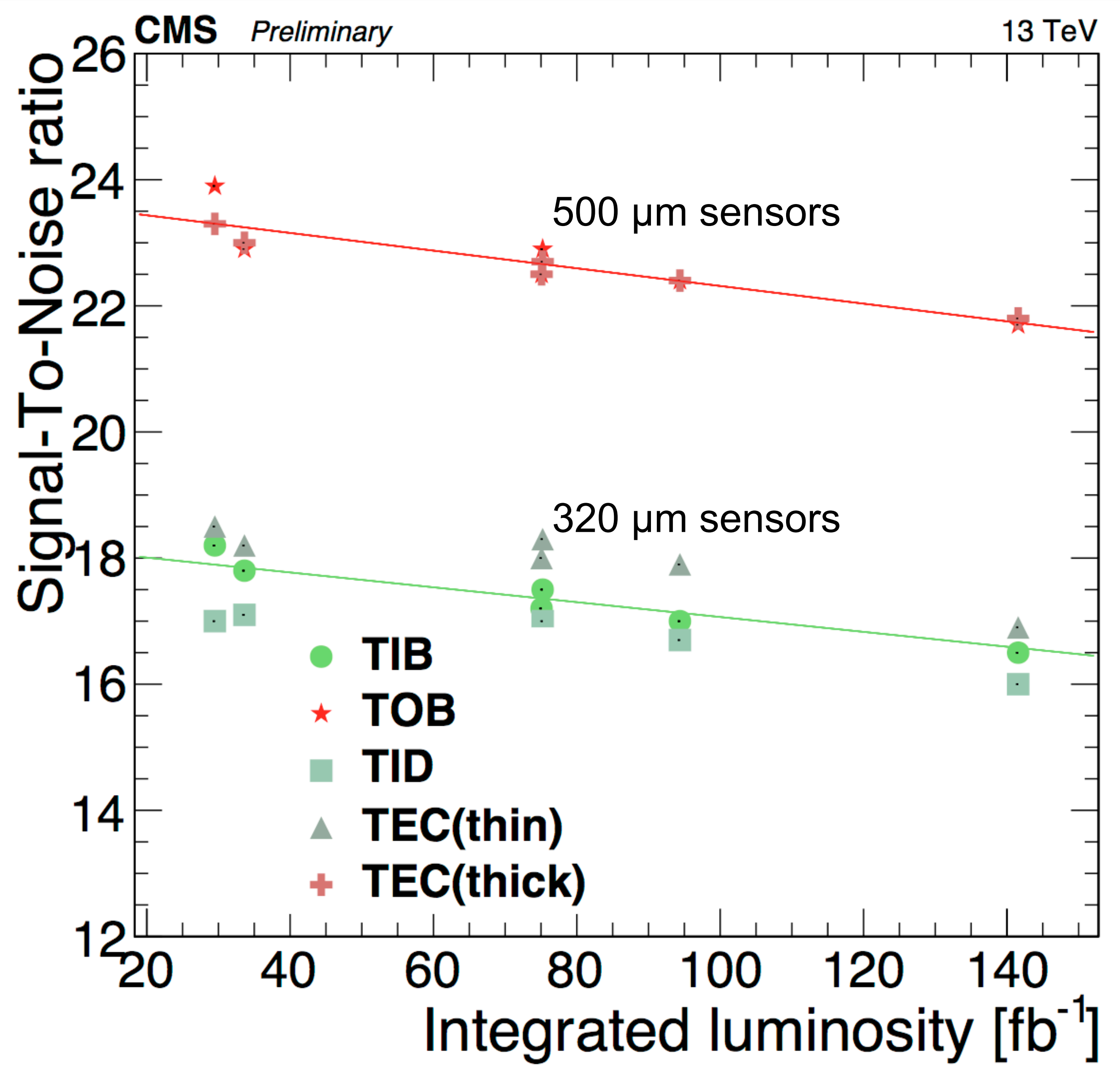



- Noise is regularly monitored and updated thanks to dedicated runs
- Noise in MC has been updated to reflect detector changes
- S/N ratio is regularly monitored (within LHC fill, … )

- Fit the S/N distribution with a convolution of ***Laudau & Gaussian*** functions
- MPV is reported
- Results obtained with FE chips (APVs) working in *deconvolution* mode (weighted average of 3 consecutive samplings)

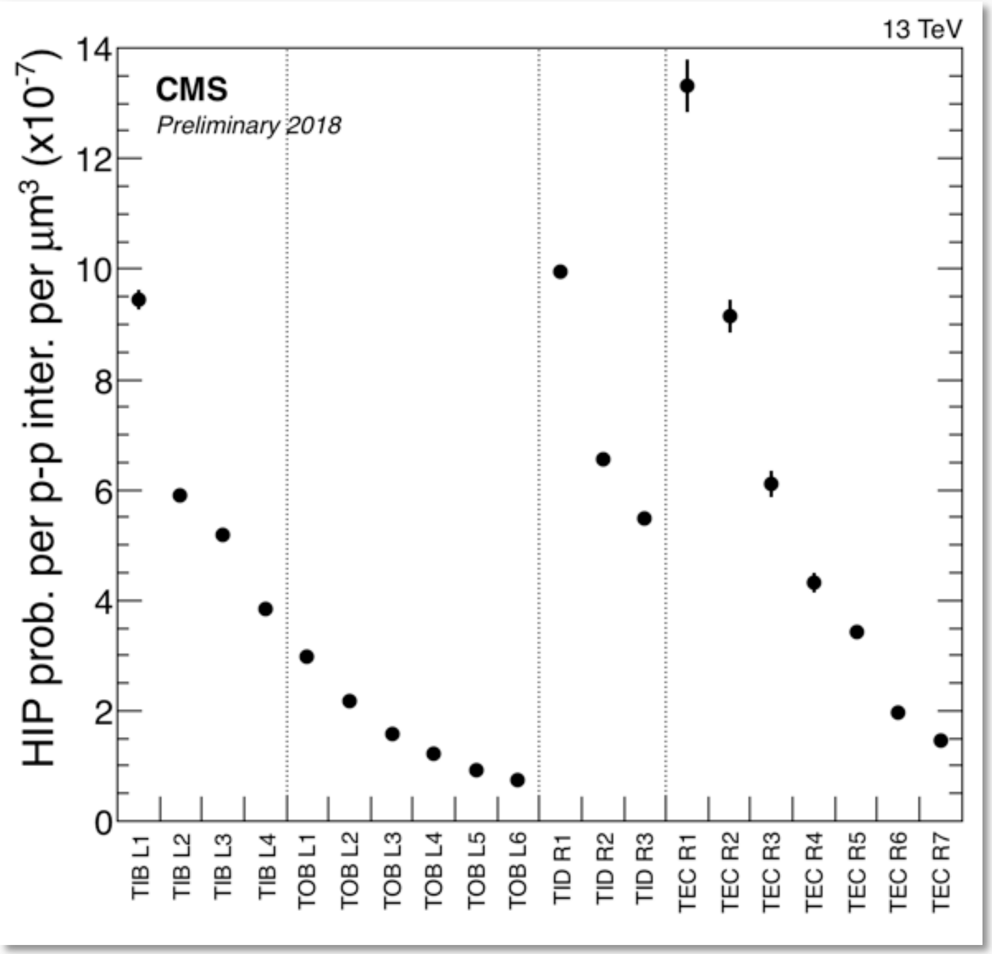
# Evolution of S/N during Run II

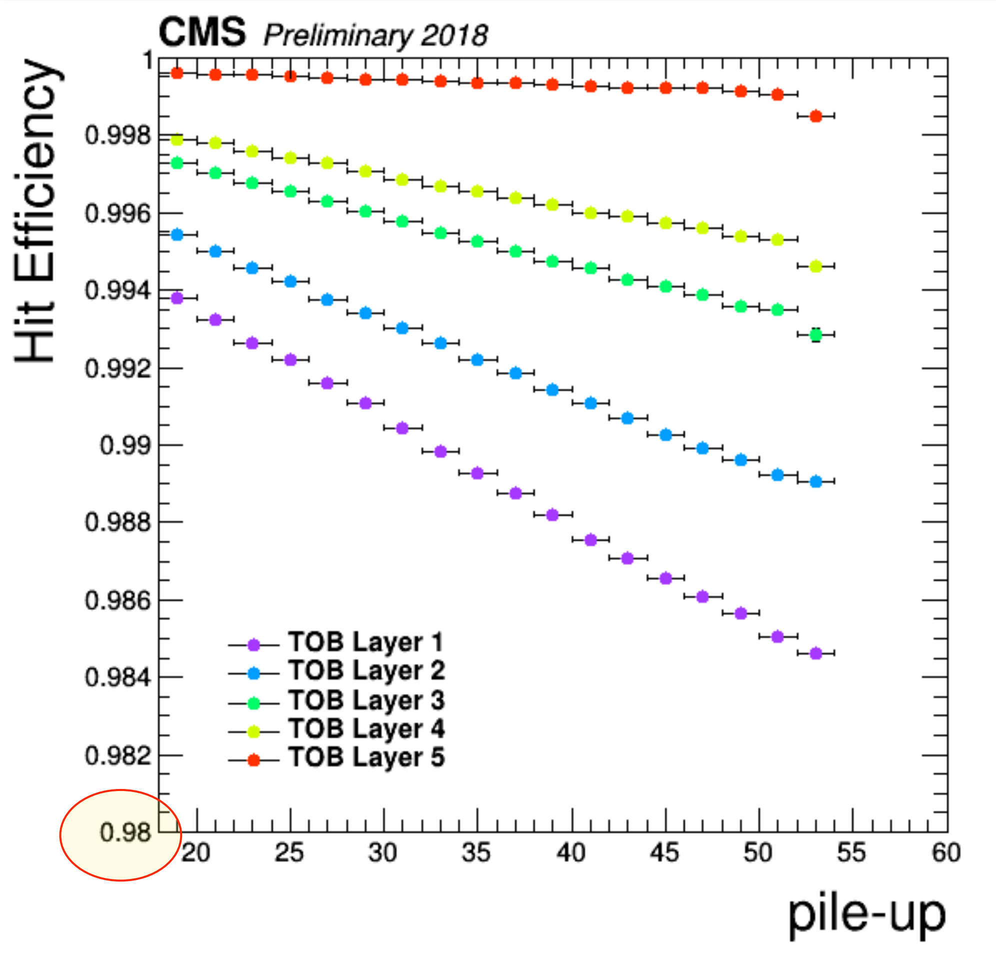



- S/N **decreased** with the integrated luminosity by **~ 5% during Run II**
- This effect is taken into account in the simulation through an **update of the noise conditions**
- Even if we linearly extrapolate for *end of Run III*, we might still have S/N > 15 for thin sensors

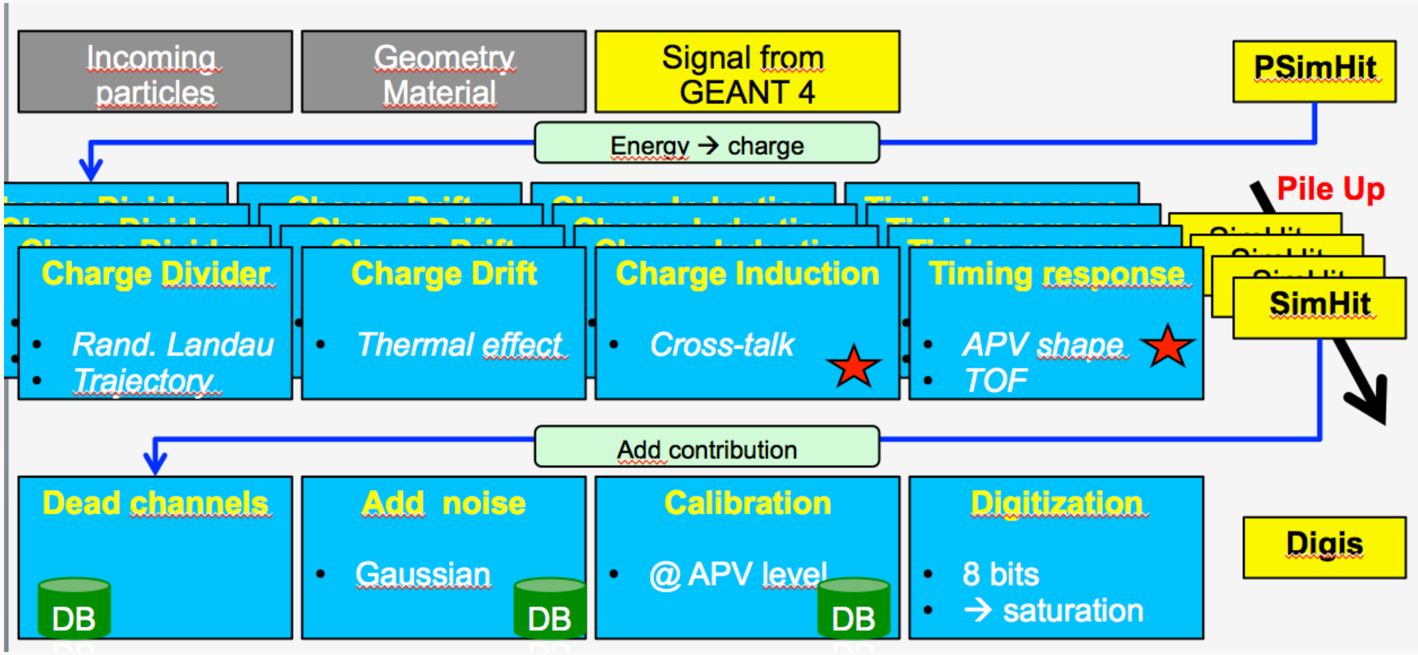
# Dead time & inefficiencies

- Nuclear interactions can induce « **Heavy Ionizing Particle** » events where a charge deposit much larger than MIPs (10-1000x) can **saturate the electronics** and induce a **dead time**.
- HIP probability has been measured in the Tracker (per interaction and per unit of volumn).
- HIP events are responsable for the small **hit inefficiency** (<2%) that has been independantly measured as function of pile-up (or luminosity).



# Dead time & inefficiencies



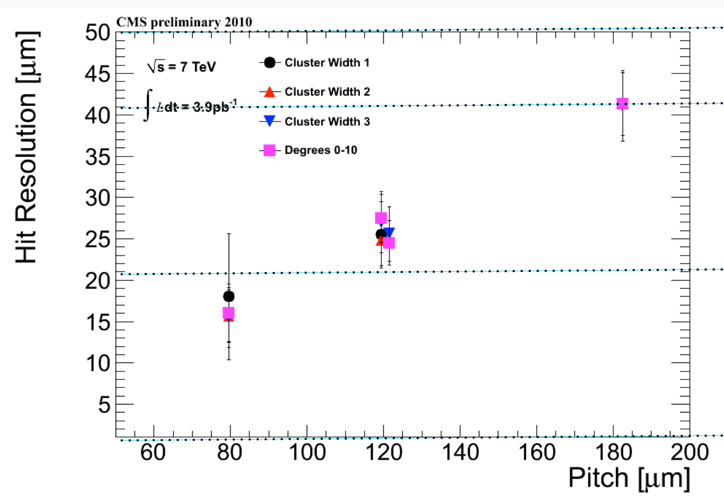

- HIP effects were known and studied prior to data-taking
- The current simulation framework include the possibility to introduce inefficiencies
- Ongoing work done to include our current knowledge of the inefficiencies in the simulation

# Hit resolution

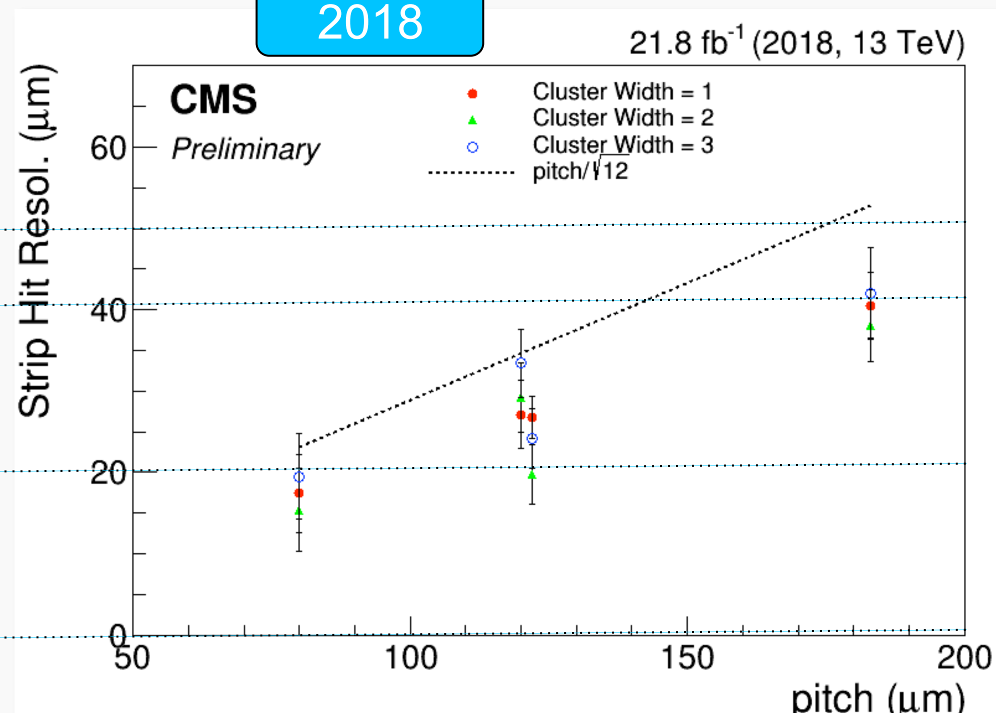
The hit resolution achieved is better that pitch/√12 thanks to the charge sharing and the barycenter algorithm

Measurement based on a « pair method » which consists in selecting pairs of hits in overlapping sensors Differences between the hit positions allow to infer the resolution

2010




2018



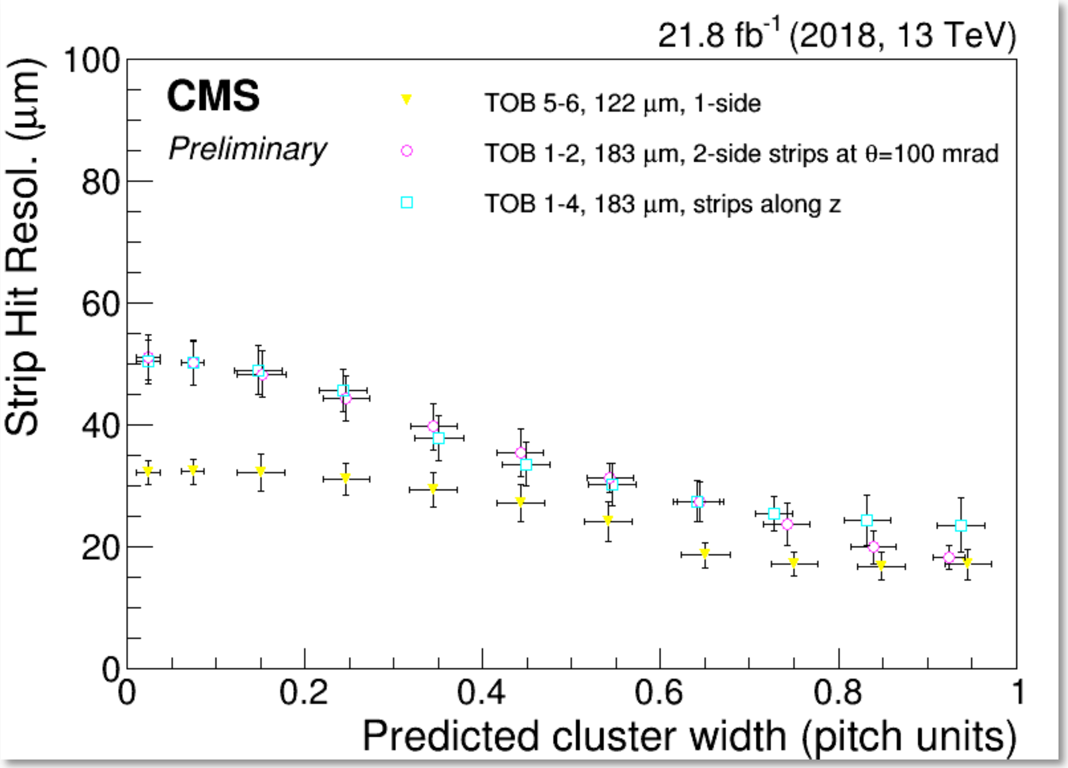

**The hit resolution remains almost unchanged since the beginning of Run I**

# Conclusions

- The CMS tracker simulation structure remained almost unchanged since Run I
- In general, the **data/MC agreements are good** and sufficient to describe properly downstream quantities (tracking, ⋯)
- Nevertheless, efforts were done during Run II to further improve our simulation and **updates** were done through:
  - DB conditions (noise, gain)
  - Parameters (cross-talk, APV pulse shape)
- **Radiation damage effects** injected in the simulation are thus
  - Gain (optical chain) → decreased
  - Noise → increased
  - Cross-talk → decreased
- Dead time & inefficiencies
  - Measurements have been done
  - We expect to inject that knowledge in the simulation soon
- **Hit resolution** almost **unchanged** since the beginning of Run I

# Backup

# Hit resolution




The resolution is measured as function of the predicted cluster width which depends on the trajectory

$$\frac{thickness}{pitch} \,|\tan\theta\cos\phi + \tan\theta_L\,|$$

- In the reconstruction, we need to inject a « Cluster Position Error » (CPE).
- Parametrization have been made separately for small and large width clusters.
- For cluster with less than 5 strips, the CPE depends on the predicted cluster width.
- Hit resolution measurements validate this parametrization.