ATLAS BEAM CONDITIONS MONITOR SIMULATION

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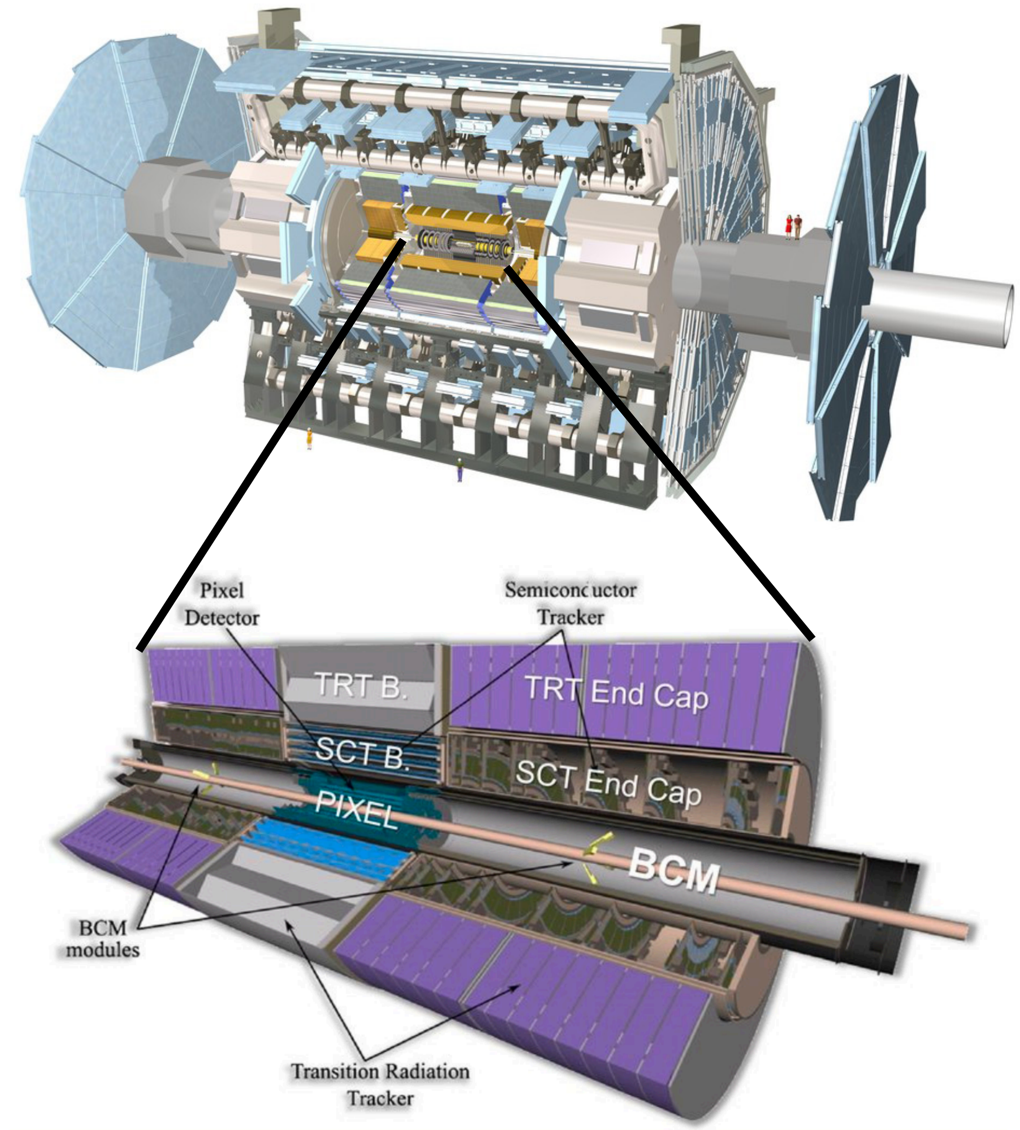
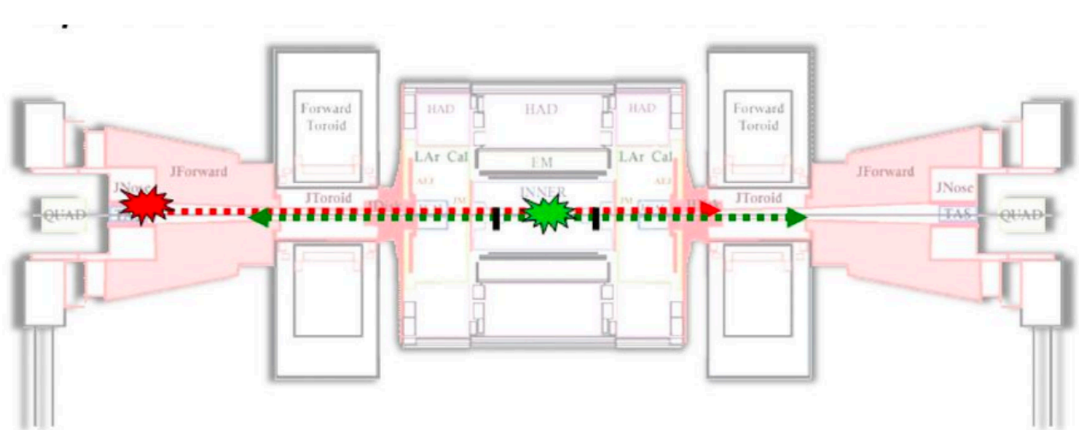
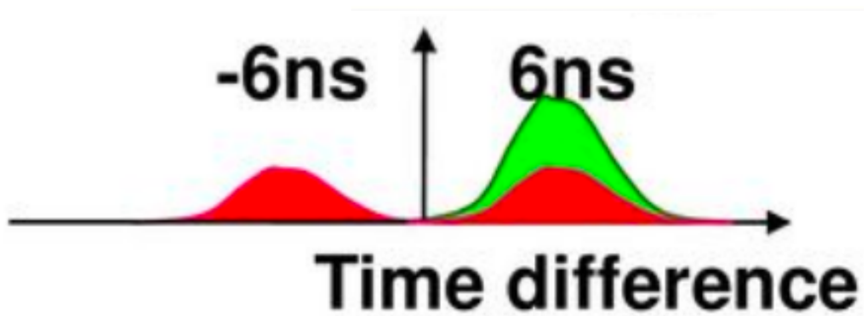
IJS

Beam conditions monitor (BCM)

- BCM is a device for monitoring the rate of non-collision and collision events
- Preventing detector damage in case of a magnet failure or error during injection phase
- Luminosity measurement
- Two BCM stations installed at both sides of interaction point: z_{BCM} = ±1,84 m (= ±6,25 ns)
- Time measurement employed to separate collision and non-collision particles
- Fast processing times needed (fast signal rise time, narrow width and short baseline restoration)

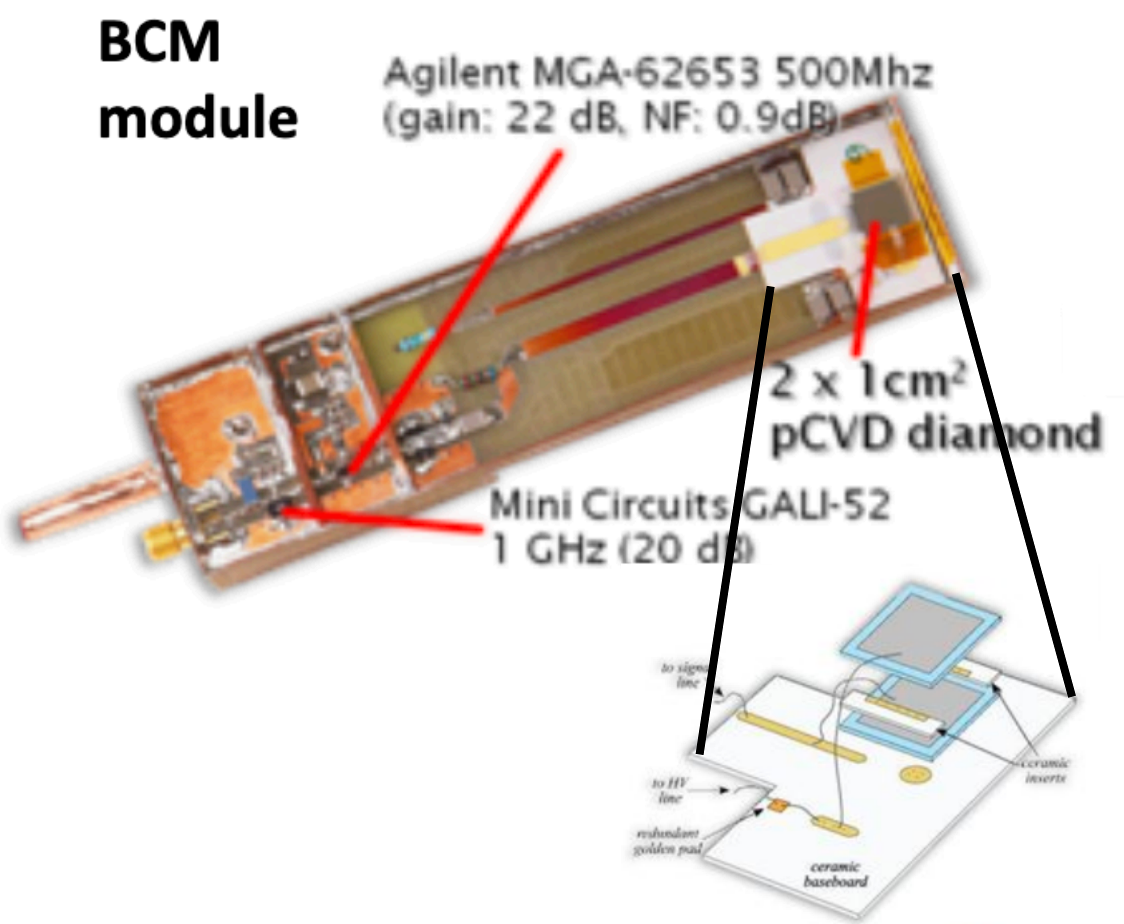


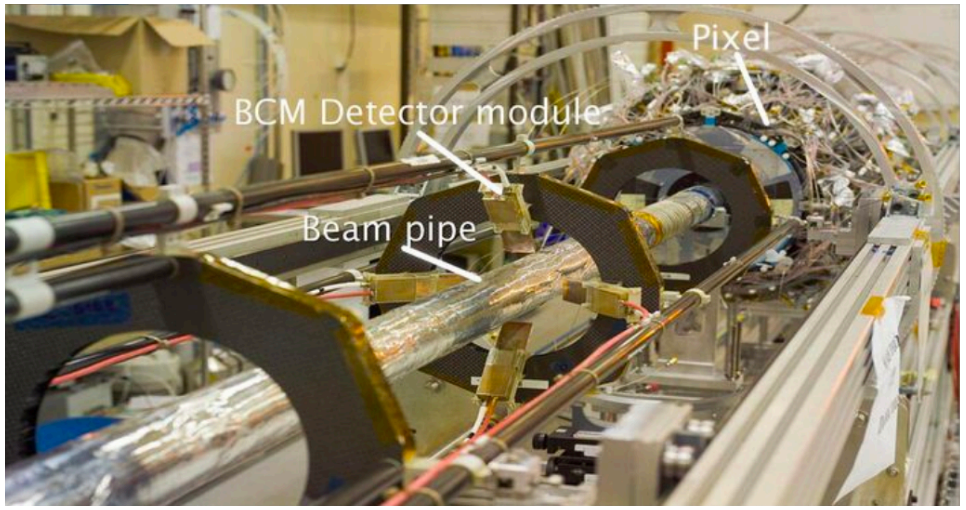




BCM modules

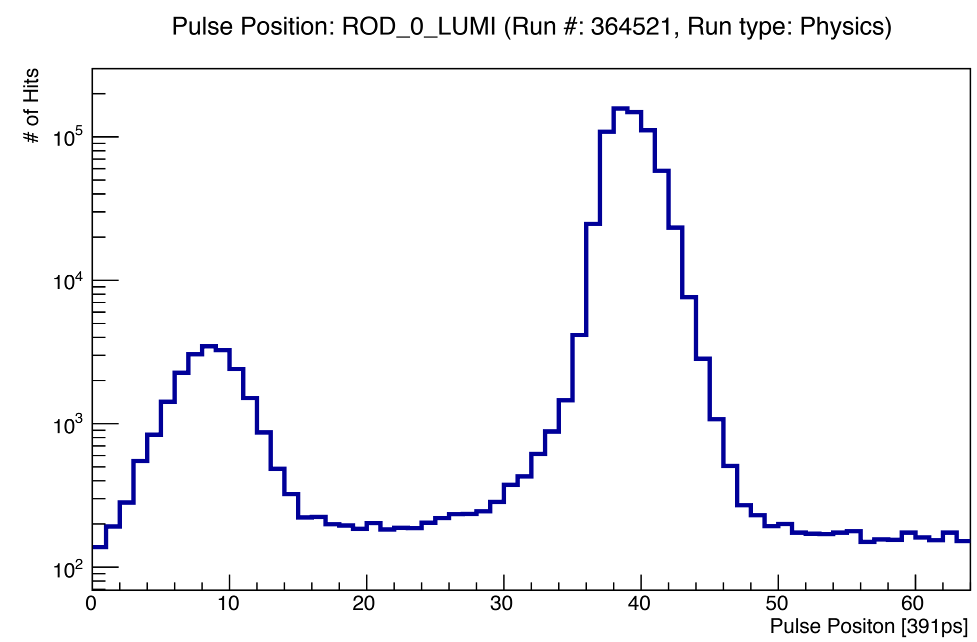
- 4 modules placed symmetrically around the beam pipe at $\varphi = 0°$, $\varphi = 90°$, $\varphi = 180°$ and $\varphi = 270°$
- Mounted at angle 45° towards the beam pipe in order to increase the signal
- BCM sensors located in the endpoint of the module: r = ~55 mm, η = ~4.2
- Sensors are made of pCVD diamonds:
  - High charge mobility
  - Radiation hardness
  - Almost negligible leakage current
- Box is made of G10, with the inner sides covered with a 35 μm thick Cu layer ➔ Shielding of the amplifiers from EMI

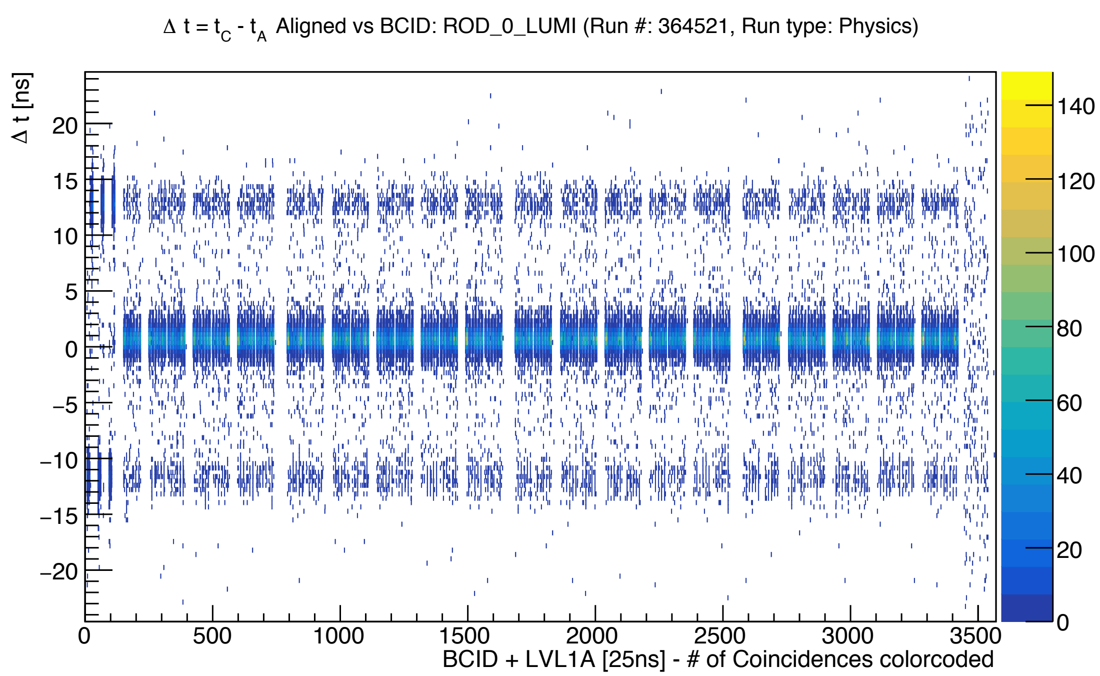


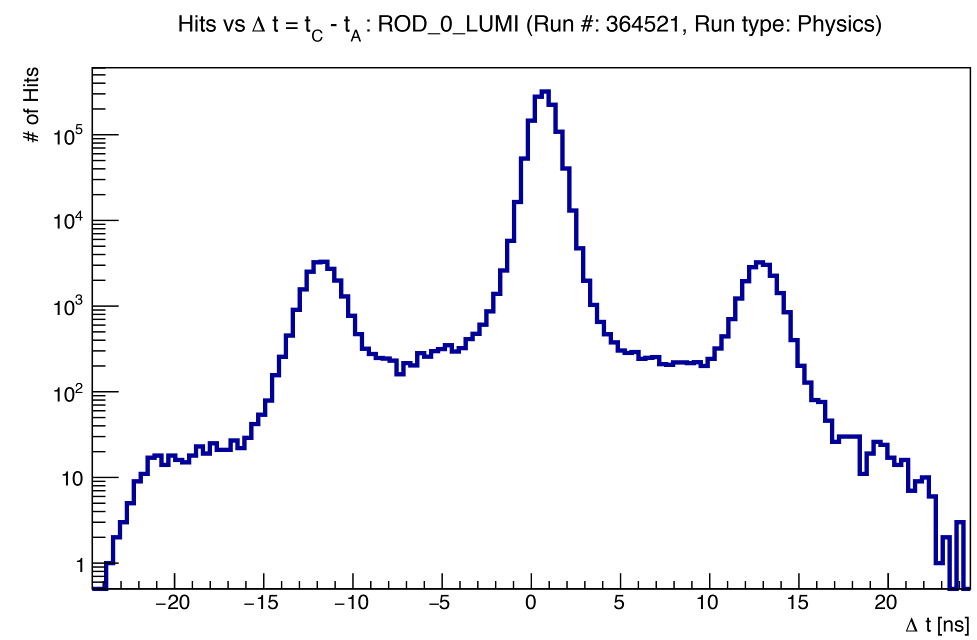


BCM data - time distributions

- Good separation of signal and background in pulse position of a single module and Δt of the pulses from the two BCM stations (two sides):
  - Collision events at $\Delta t = 0$
  - Beam-halo and beam-gas scattering at $\Delta t = \pm 12.5$ ns
  - Background due to soft particles

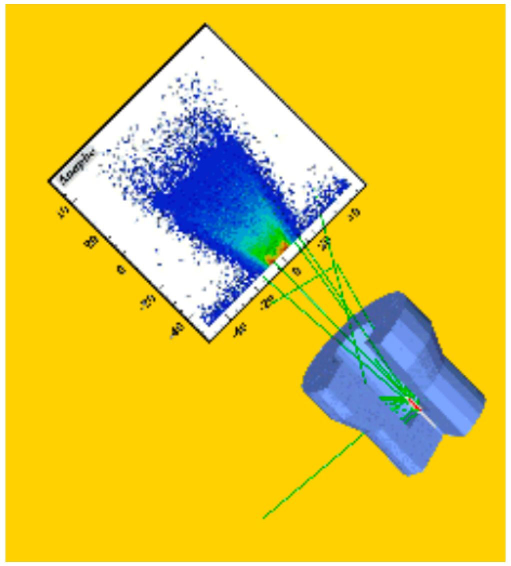


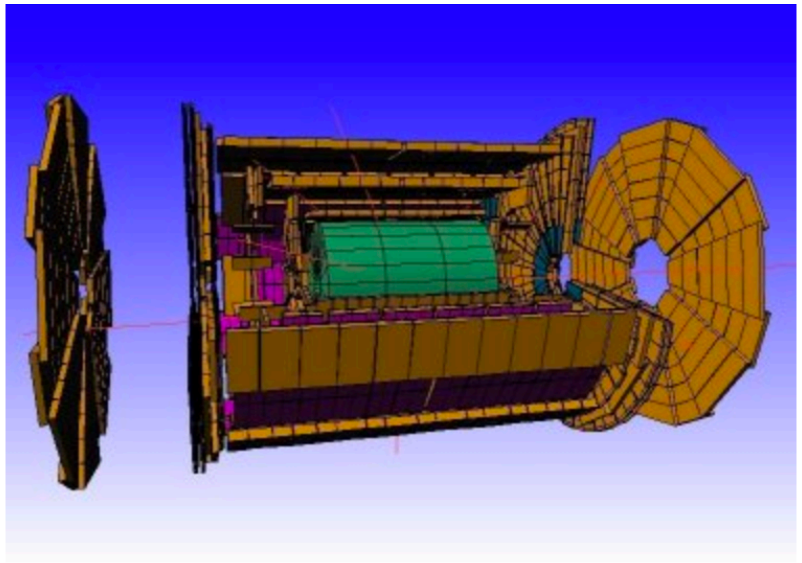


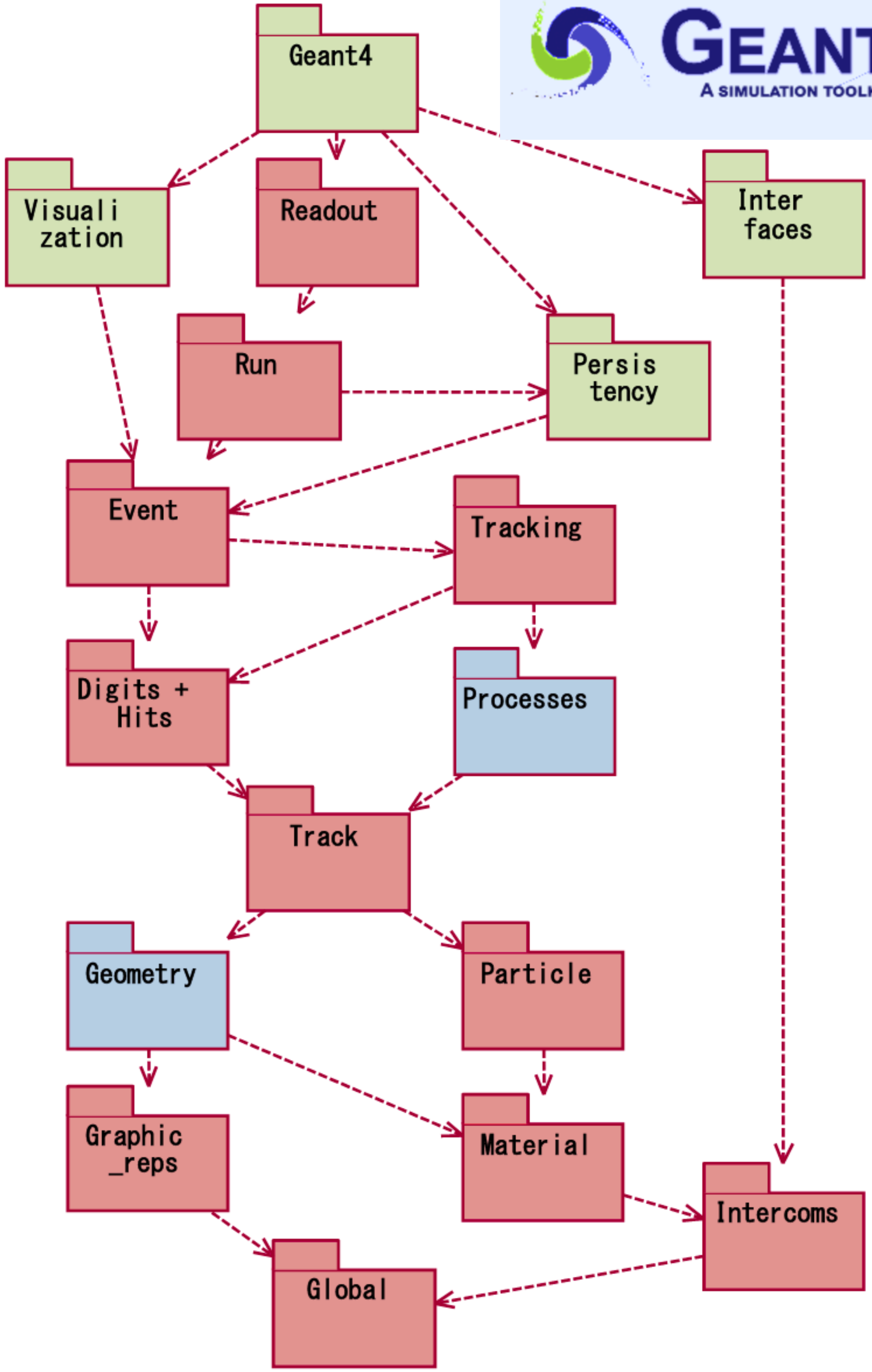


GEANT4 toolkit

- Toolkit for the simulation of the passage of particles through matter
- Besides HEP its applications cover also medical and space science
- Basic unity of a simulation is event
- Each event contains initial vertices, with outgoing particles (inputed or generated in a GEANT4 application)
- Initial and simulation generated particles are propagated through material in discrete steps

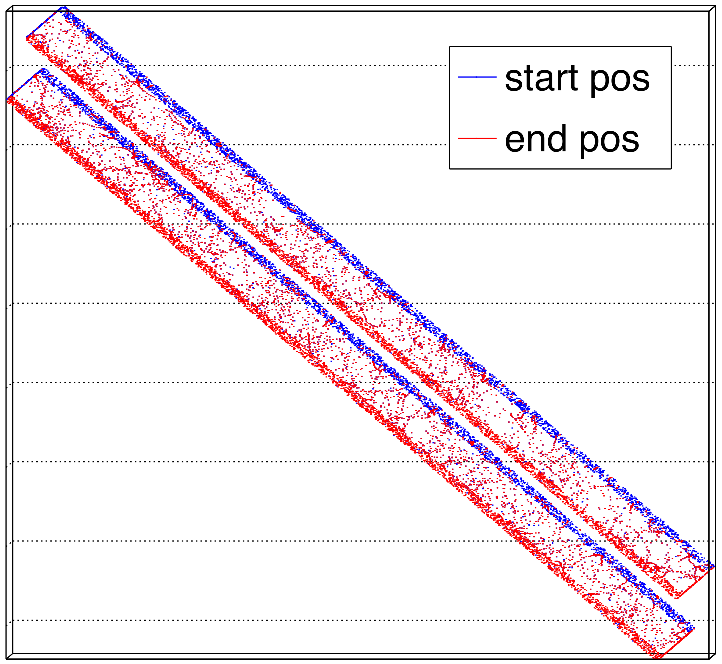


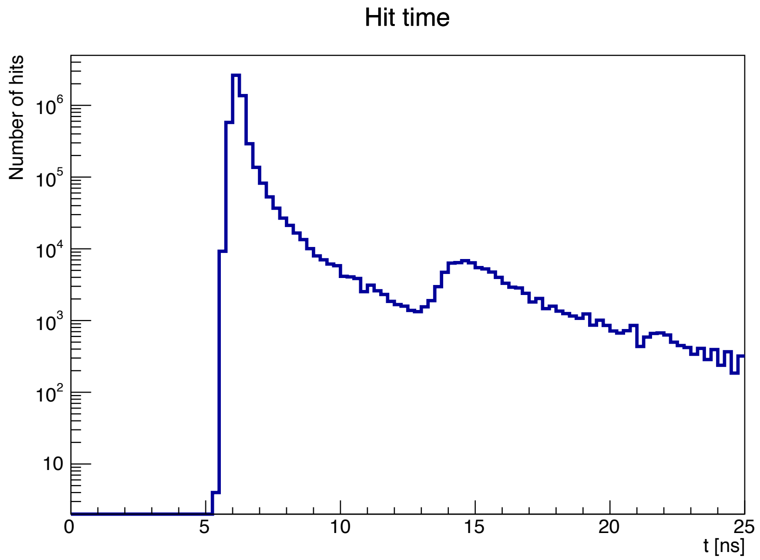


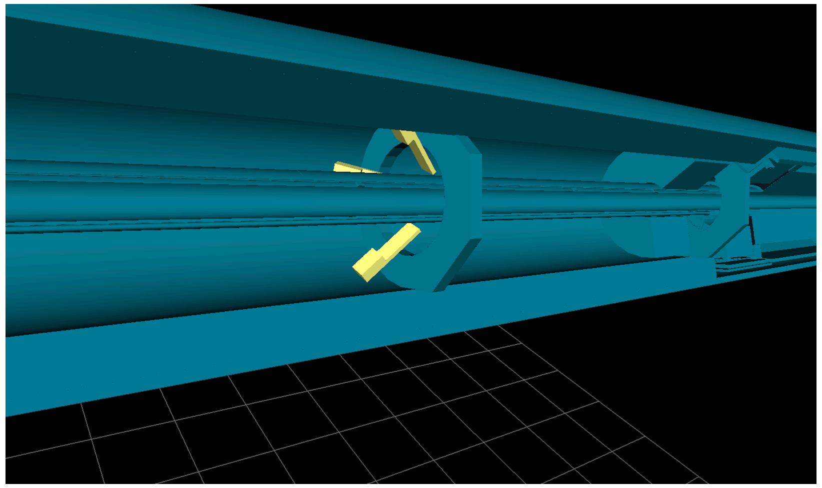


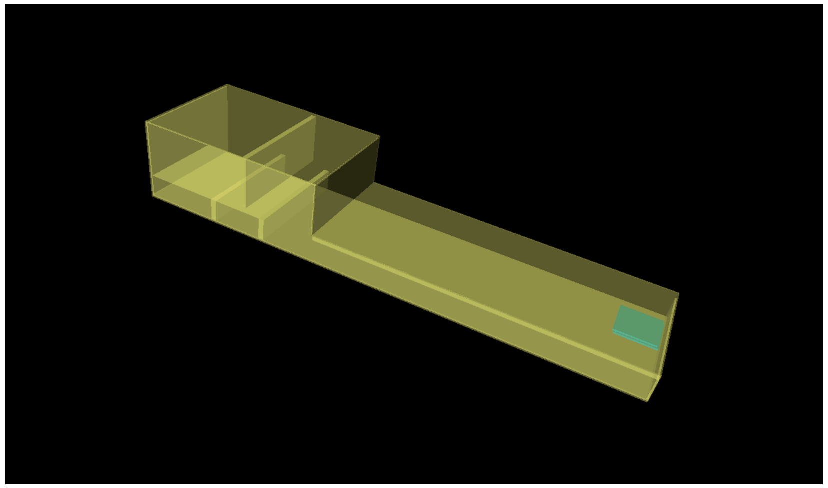
BCM simulation

- BCM volumes included in the ATLAS simulation
  - Studies of the BCM performance ➔ design of the BCM for high luminosity run (BCM’)
  - Scattering of particles on the BCM modules
- Only diamond volumes are sensitive
- Output contains information about: hit start/end position, energy loss, time, truth particle, BCM module and diamond ID



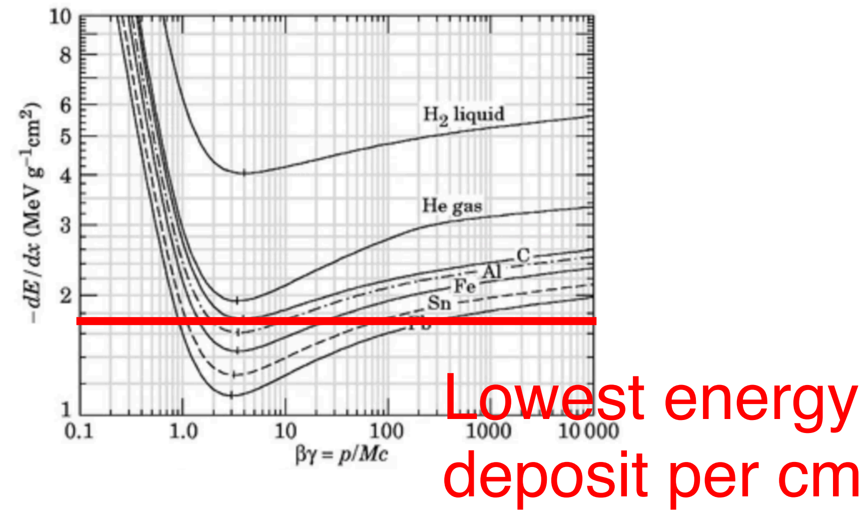


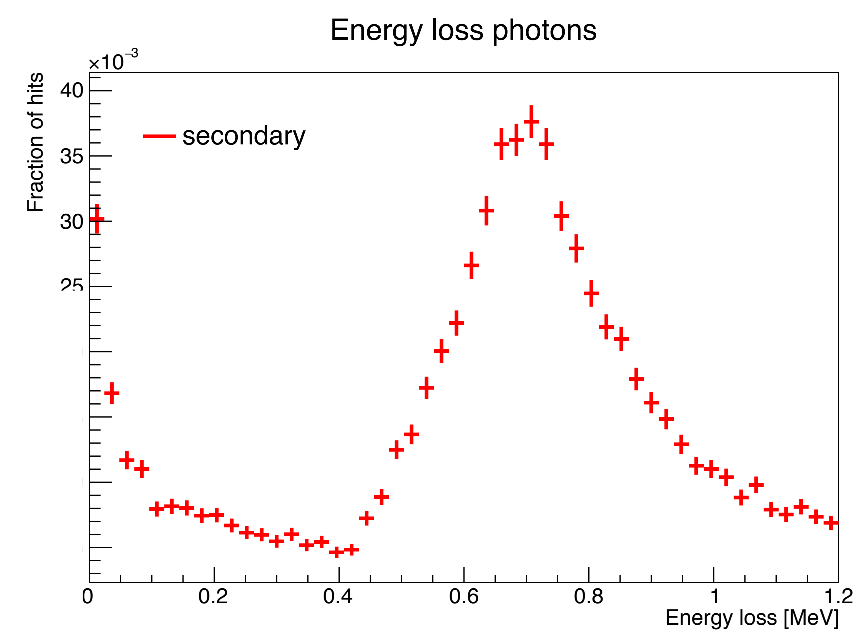


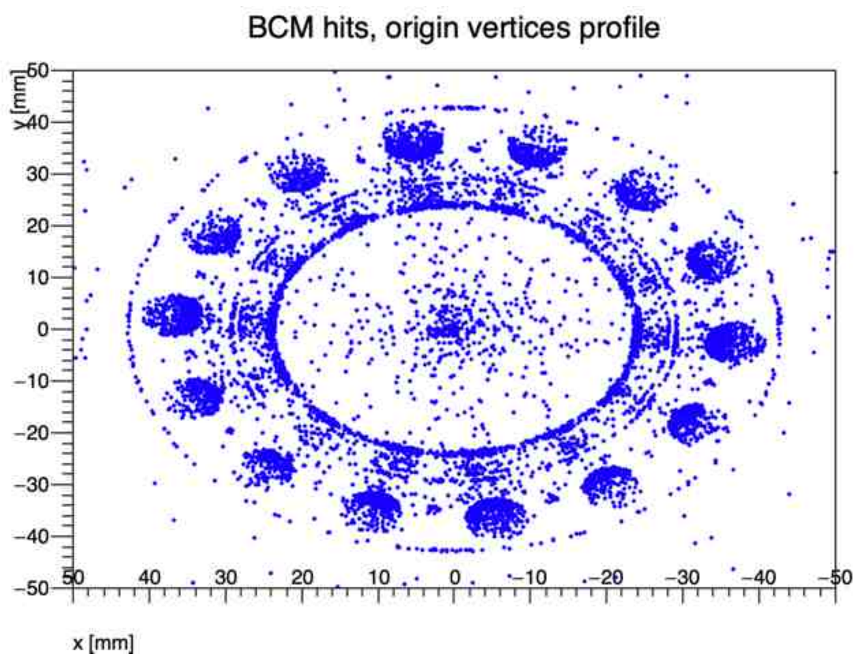


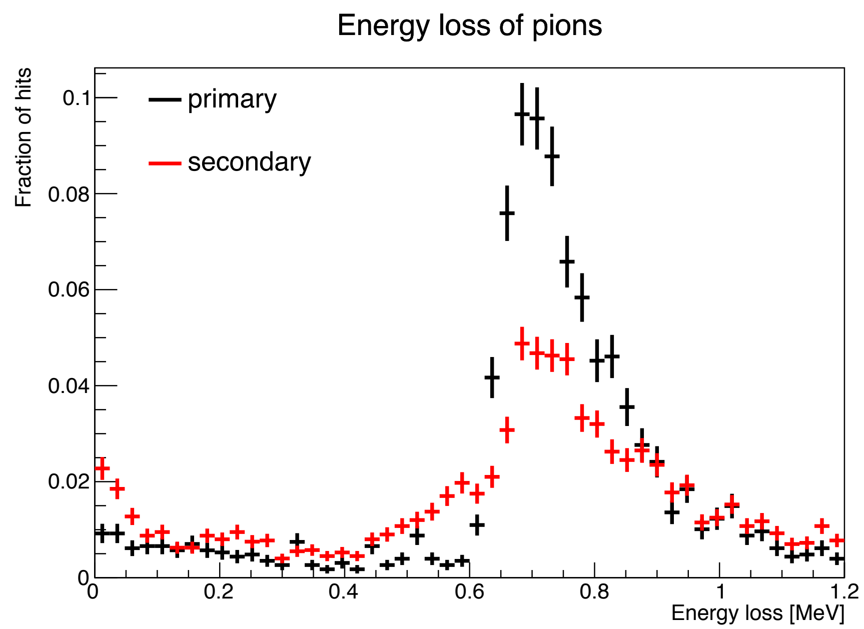
BCM simulation

Particle type	Percentage of primaries	Percentage of secondaries
Photons	0,0%	67,9%
Pions	6,5%	11,4%
Electrons	3,2%	4,7%
Protons	0,2%	1,4%
Rest	1,1%	6,7%
Total	8,0%	92,0%



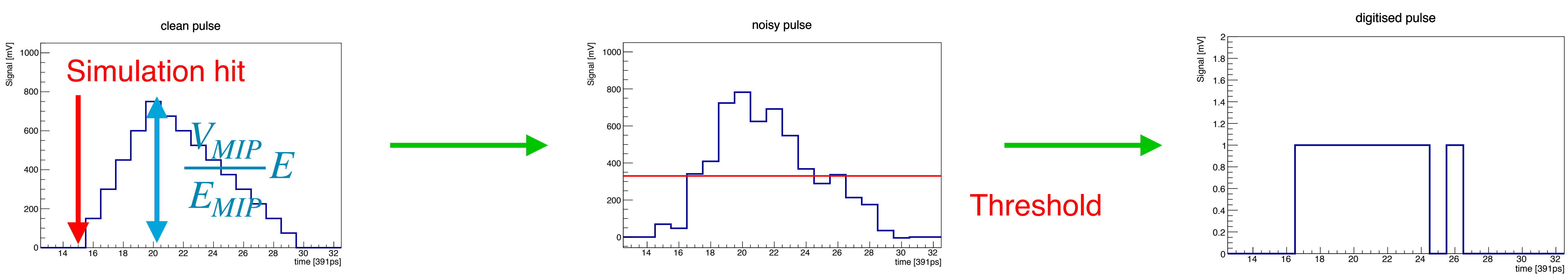






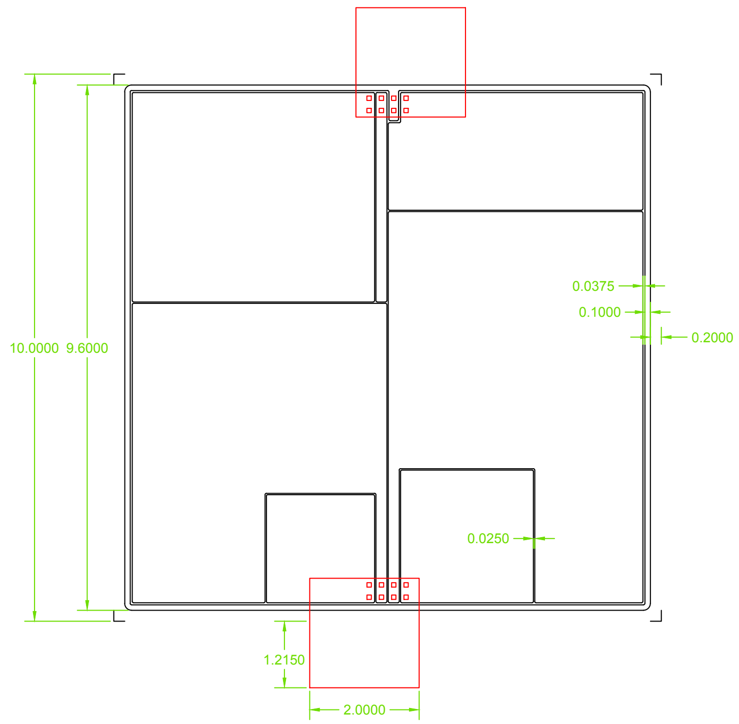
BCM digitisation

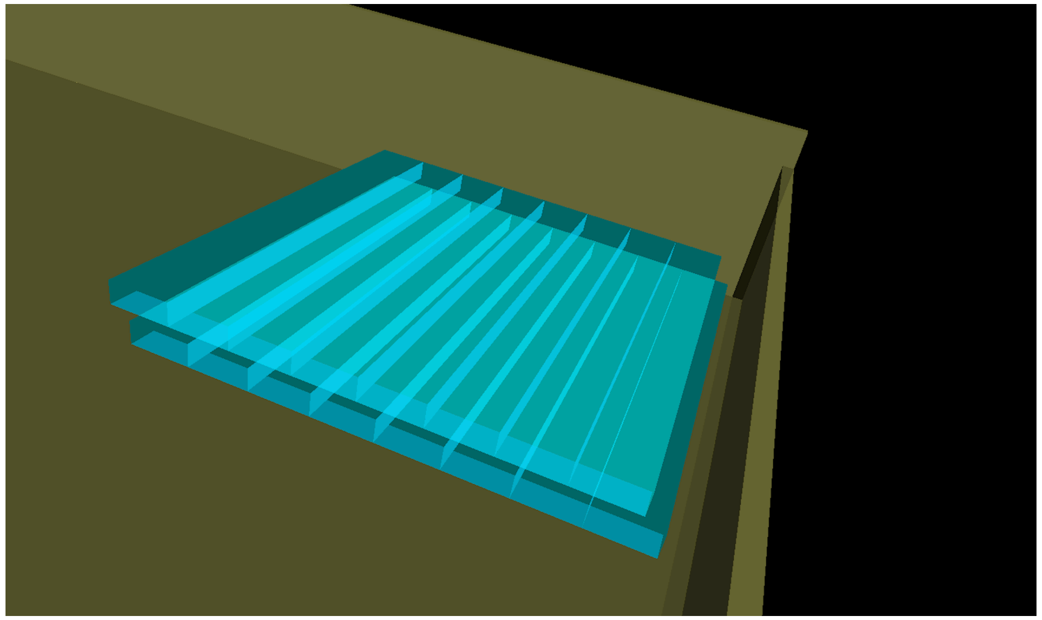
- ATLAS detector response is modelled in two steps: simulation and digitisation: in digitisation truth energy deposits from sensitive detector volumes are transformed into signal (charge collection efficiencies applied, time response, noise, detector resolution)
- In BCM signal is proportional to the energy deposition
- Pulses have triangular shape, with fixed rise and falling time
- Gaussian noise added on top of the pulse
- Splitting of the signal to luminosity and abort
- Digitisation of the pulse: thresholds applied in each of the 64 time windows for both signals



BCM for high luminosity runs

- In Run 4 luminosity is expected to be order of magnitude higher
- BCM will need to cover wider dynamical range in terms of hits per time unit
- For different particle flux, different sensitive area is optimal:
  - sensitive area is too large ➔ two subsequent pulses can merge
  - sensitive area is too small ➔ larger statistical fluctuation
- BCM sensors are going to be composed of several pads, with different curvatures
  - Difficulty: How is the charge, deposited on a boundary, going to be shared among different pads?





Conclusions

- BCM monitors beam confinement and measures luminosity
- Collision and non-collision events are discriminated, based on time measurement
- BCM for high luminosity needs to cover broader dynamical range
- Splitting the sensor into pads with different shapes
- Simulation is very important tool study of the performance of BCM’
- Sharing of the charge needs to be understood and thus accurately modelled in BCM simulation