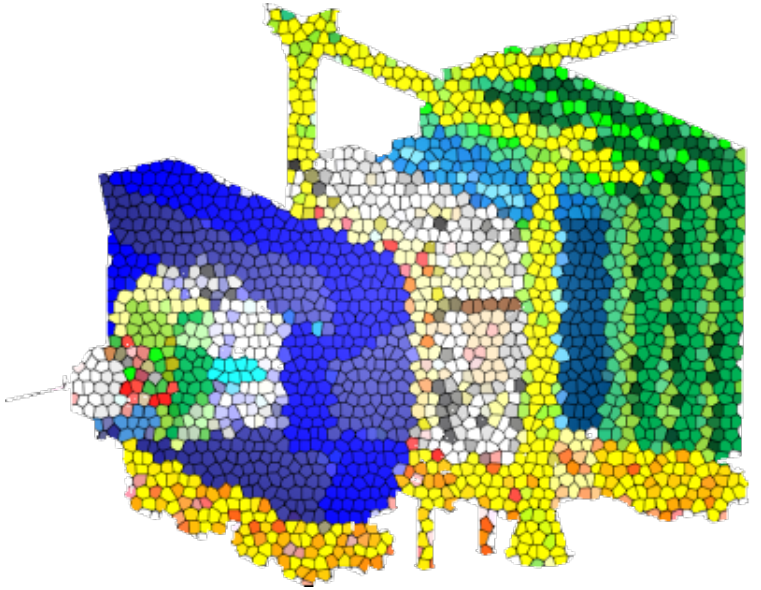
Simulation status

Mark Whitehead

Gloria Corti, Michal Kreps

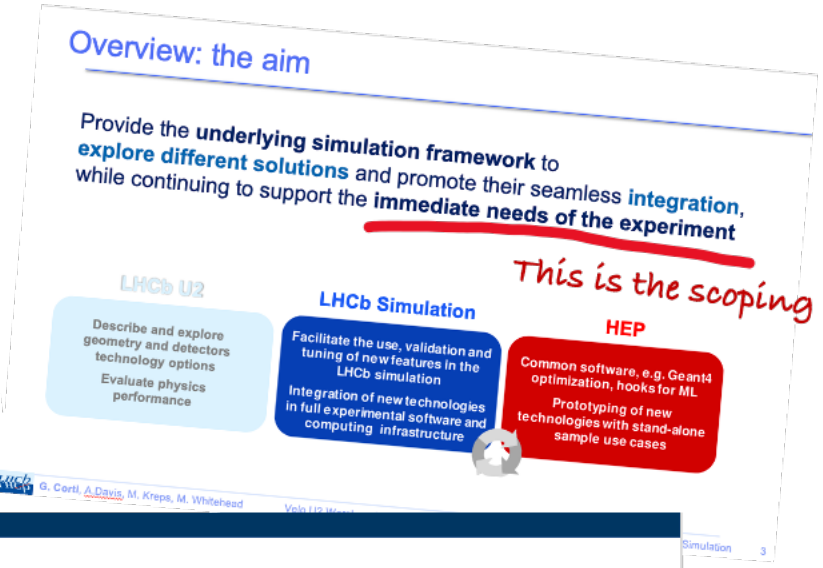
On behalf of the Simulation Project



Science and Technology Facilities Council

University of Glasgow

Simulation and Upgrade 2

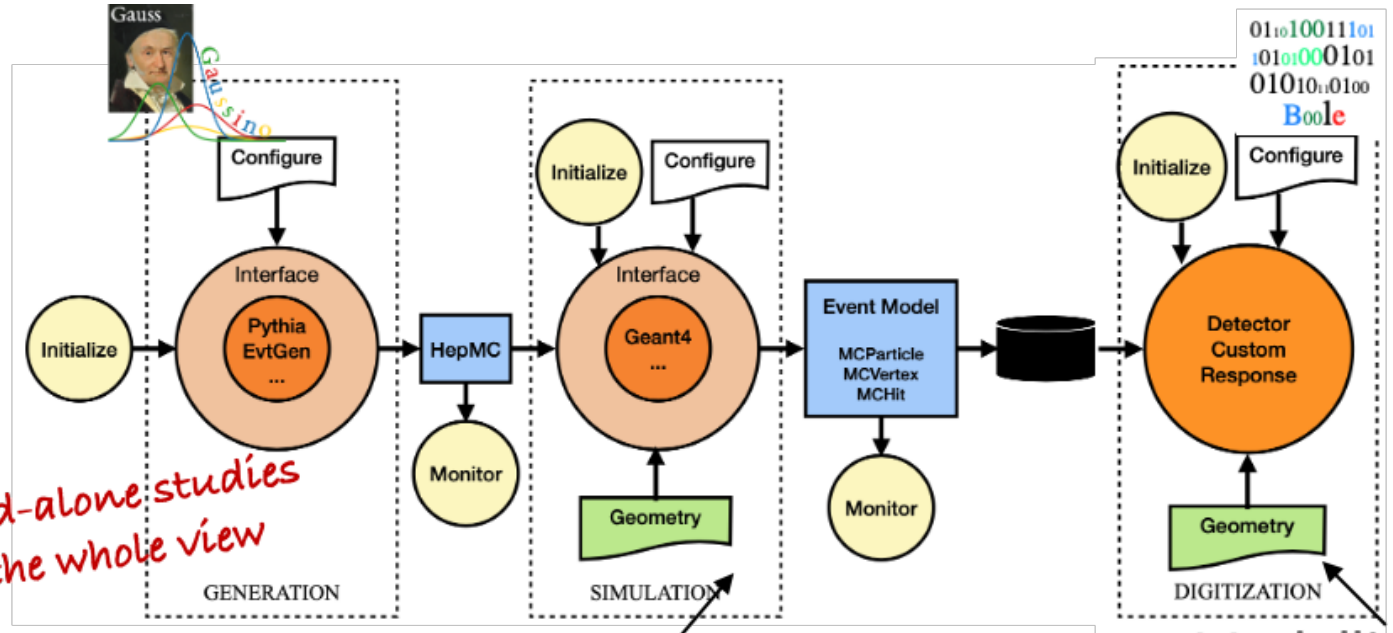


This is the scoping in the next 4 months

Focus on aspects critical for U2 studies in Spring 2024

keeping in mind it is just the start...

Reminder - simulation software



Helps for stand-alone studies
Essential for the whole view

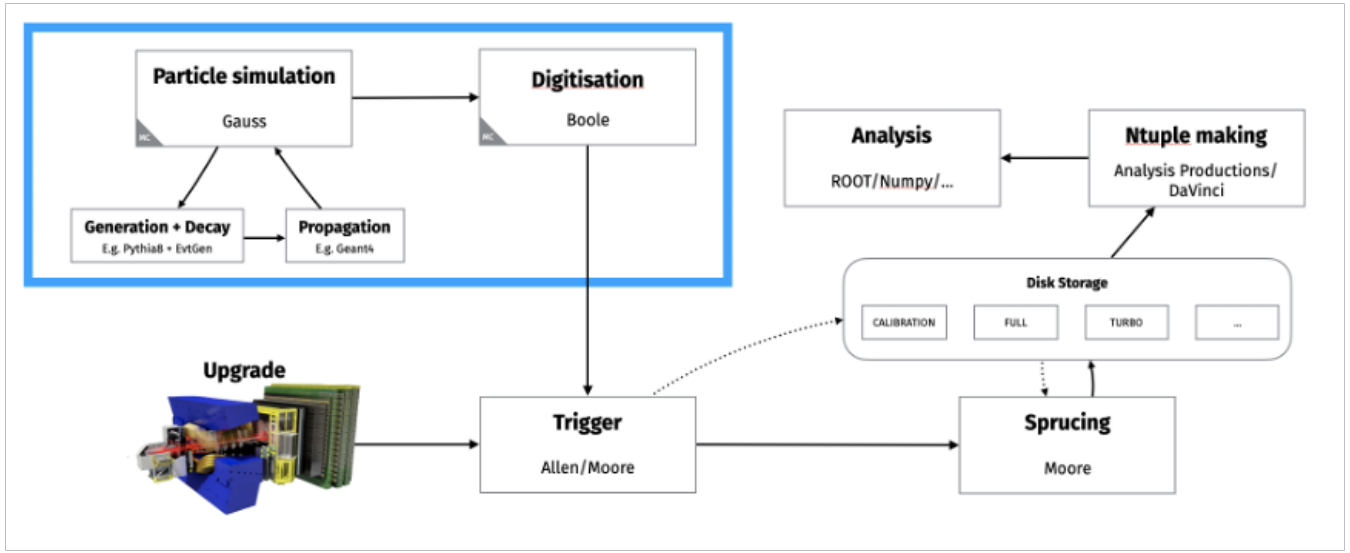
Transport of particles through detector layout and modelling of physics processes occurring with material

Modelling of detector and its electronics response including imperfections

Geometry and conditions are critical inputs to simulation

Reminder - MC productions

MC productions are typically much more than just *simulation*



Simulation → Digitization → Reconstruction → Trigger emulation → Sprucing

Scoping	Yes	Light	Studies / Prototypes	No	No
TDRs	Yes	Yes	Yes	Studies / Prototypes	No
Exploitation	Yes	Yes: As-data	Yes: As-data	Yes: As-data	Yes: As-data

Requirements for minimal full U2 sim?

For any new detector we need

- **Detector** – geometry model implemented using DD4Hep
- Handling of **MC hits** in sensitive detector elements
- Configuration in Gauss
- Event model classes (at least MC)
- Translation of MC hits into objects for the reconstruction to use
- **the basic software infrastructure**
  - detector specifics need to come from the **detector groups**
- support for sub-detectors
- modelling of detector infrastructures (magnet, beampipe, ...)
- computing infrastructure

What infrastructure do we need?

- On the timescale of the scoping document, what do we need?
  - Generate upgrade events with Gauss-on-Gaussino in the production system (S)
  - Versioning of geometry in Detector (C)(S) first, then (D)
  - Simulation branch for conditions (C)(S) first, then (D)
  - Detector restructuring/refactoring to allow common classes (C)(S) first, then (D)
  - Detector geometries and minimum detector element classes (D)
  - Digitisation - infrastructure for lighter/pass through options (C)(S)
  - Digitisation - sub-detector code (D) Not for scoping

(S) = Simulation Group, (C) = Core Software and (D) = Detector groups

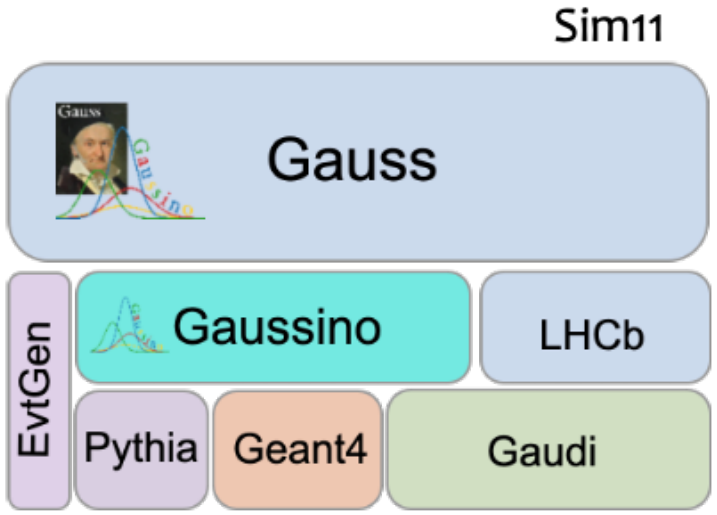
What infrastructure do we need?

- On the timescale of the scoping document, what do we need?
  - Generate upgrade events with Gauss-on-Gaussino in the production system (S)
  - Versioning of geometry in Detector (C)(S) first, then (D)
  - Simulation branch for conditions (C)(S) first, then (D)
  - Detector restructuring/refactoring to allow common classes (C)(S) first, then (D)
  - Detector geometries and minimum detector element classes (D)
  - Digitisation - infrastructure for lighter/pass through options (C)(S)
  - Digitisation - sub-detector code (D) Not for scoping

(S) = Simulation Group, (C) = Core Software and (D) = Detector groups

First versions for most of the (D) parts too for tracking detectors

Sim11 - Simulation software framework



Gaussino

- core simulation framework
- experiment-independent parts extracted from Gauss
- minimal functionality in stand-alone mode
- test-bed for new ideas/developments
- collaborate with SFT Key4Hep

GitLab `master` branch
Up to date with latest Gaudi, Detector and LHCb

Gauss[-on-Gaussino]

- built on top of Gaussino
- adds LHCb-specific parts

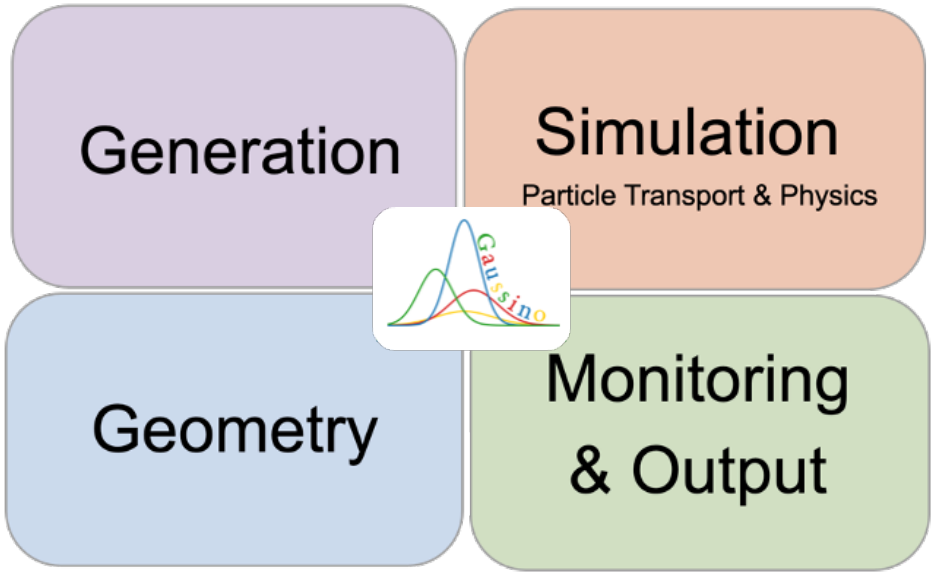
Gaussino documentation

Gauss documentation

Sim11 - Simulation software framework

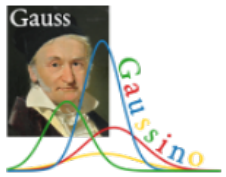
- Pythia8 & EvtGen working for ≳80% needs (signal only ST, idea for MT)
- WIP on MEC (MadGraph)
- Configurable beam and 3D luminous region, WIP for 4D
- In time pileup with luminosity leveling available, WIP for decaying

- Geant4 MT 10.7, comparison to 10.6 (Sim10) ok
- Full support for custom simulation
- ML serving infrastructure
- WIP for optical physics



- subdetectors using DD4Hep supported
- WIP to use new Conditions
- relies on Detector project
- WIP for U2 baseline

- PyTests
- LHCbPR Run3 detectors comparison DetDesc vs DD4Hep,
- WIP to introduce Run5 monitoring in LHCbPR
- WIP to add MT compatible CPU and memory monitoring in LHCbPR

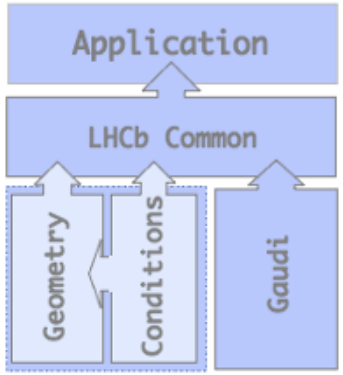


Gaussino and Gauss Configurables

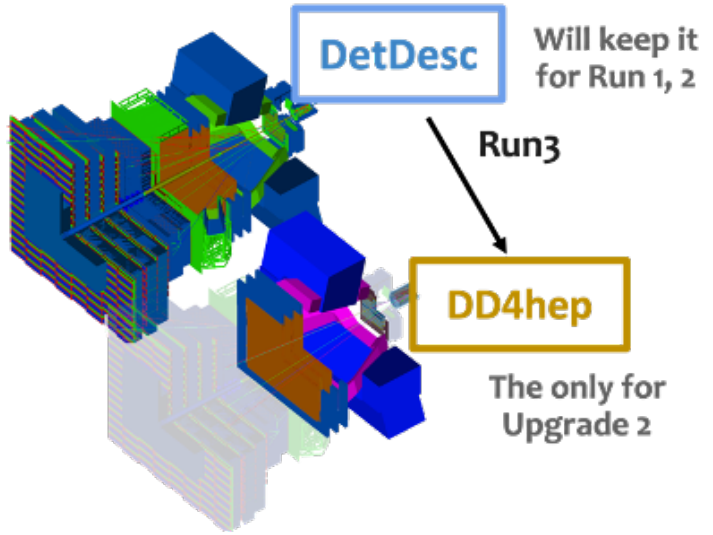
- WIP on Run3 and Run5 configurations for test and initial productions
- WIP on flexible and safe gaudiconf2-based configuration (not for scoping)

Geometry in simulation

- Gauss is the main customer for geometry at this point in time



- Pre-requisites for DD4Hep simulation with Sim11
  - Detector Project
    - xml files in compact xml directories
    - Detector elements with sensitive detector information
  - Gauss-on-Gaussino
    - Python configuration file in Sim/Gauss/python/Detector



- Combination of detectors chosen in Detector/Gauss
- Tools available or WIP to check geometry, material scans etc

Detector Software Project and Conditions

- Refactoring and restructuring of Detector completed
  - A released version must be able to create the representation of all versions of LHCb needed by the experiment
  - Choose a version by selecting the required LHCb.xml file
    - Share common code, e.g. Run4 detector will reuse much of Run3
    - Directories for each Run period (3/4/5) with versioning
    - Better control sub-detectors path and versions
  - Convention enforced at GitLab CI level

A huge effort from Simulation & Core software - in particular CERN & Warwick

- Conditions are needed even if 'perfect'
  - New sim11/run5-ideal branch setup
  - Access to conditions needed also at initialisation
    - Working for magnetic field
    - Not yet for sub-detectors before passing them to Geant4, to be tackled ASAP

Sub-detectors

- Pushing to get first tracking system simulation going
  - Merge requests exist for tracking detectors
    - VP -> TV, UT -> UP and MP (+Run 3 FT with modifications)
  - Ongoing work from other sub-detectors!
    - TORCH and RICH require Geant4 physics related work, WIP
    - RICH1 and RICH2 Run3 geometry can be used as is
    - ECAL geometry, WIP

TV Detector, Gauss, LHCb and conditions

UP Detector, Gauss, LHCb and conditions

MP Detector, Gauss, LHCb and conditions

- The challenge is to put them together
  - Not a trivial task
  - Review, validate and deploy integrated detector code
  - Finding and fixing problems
  - A few things still to do in the general simulation framework
  - Meanwhile small samples produced on lxplus are being looked at and iterated upon

Software next steps

- Define datatypes for Runs 3,4 and 5 WIP
- Include LHCbPR tests for US detectors WIP
- Prepare inclusion of detector in LHCb.xml
- Correct and validate beam pipe in DD4Hep Boost priority?
- Review Detector and remove unnecessary parts e.g. BLS WIP
- Modify SciFi to remove active area covered by MP WIP
- Steering Run 5 detector in Gauss WIP
- Grid jobs configuration and propagation of options WIP
- Further improvements/changes from sub-detectors WIP
- Test and deploy light digitisation WIP

Boole - Digitisation

- Transforms hits generated in sensitive detectors by Gauss to mimic their response
- Specific simulation required for each sub-detector - match technology and electronic readout
- Detector projects provide the specific parts - Simulation project responsible for consistent integration and coherent output
- Additional hits can be added from Spillover events and LHC background

- Output: digitised data mimicking real date from the real detector
  - Emulation of raw data must be consistent with that from the firmware
    - Not necessary for new detectors for the scoping document

Lightweight digitisation

- For some detectors, we have a reasonable idea about electronics
  - E.g. SciFi for now can use Run 3 digitisation
- For new detectors it is not yet known what to do in this step
- Create lightweight option to serialise MCHits and pack them
  - Generic for all tracking detectors
  - Other detectors can use the same idea with specific developments
- Ensure we can run with a mixture of options
  - E.g. Run 3 full for SciFi + lightweight TV, UP and MP
- Work is progressing well, need a final push to get it production ready

Centralised productions

- Grid productions need SW projects and data packages need to be released and available on CVMFS
  - Gauss, [Boole] and data packages under control of the Simulation Project
  - Other parts, such as reconstruction, under responsibility of other projects
    - Not anticipated to run in production environment for scoping studies
- Once software in place, define the production models
  - LbMCSubmit makes this much easier but still requires some work
- Supporting various combinations of descoping options will be a challenge
  - Make sure we can to organise support for all detector options

Reminder: We will try to produce what is requested, but we don't define which options are required!

Timeline

end of January

Technical test of Gauss-on-Gaussino on grid

Submitted 21st Feb

early February

Delayed mid March onwards

Production campaign for Scoping document with default tracking detectors

early March

Production campaign for Scoping document with default full detector

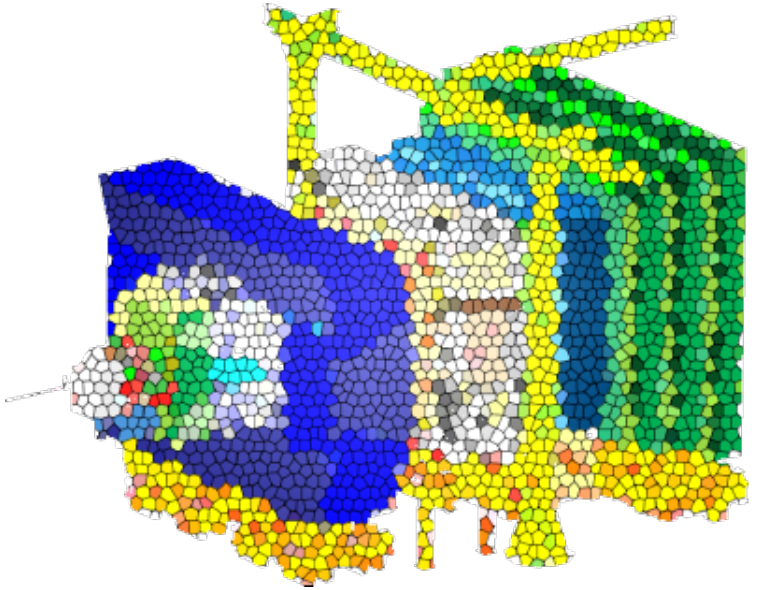
Delayed April (hopefully by middle)

April

Production campaign for Scoping document with alternative detector layouts

Hopefully won't slip much further, feedback on private samples decreases the chance of further issues

Backups



Science and Technology Facilities Council

University of Glasgow

Centralised productions 2

We want to be able to produce events with different and incremental configurations

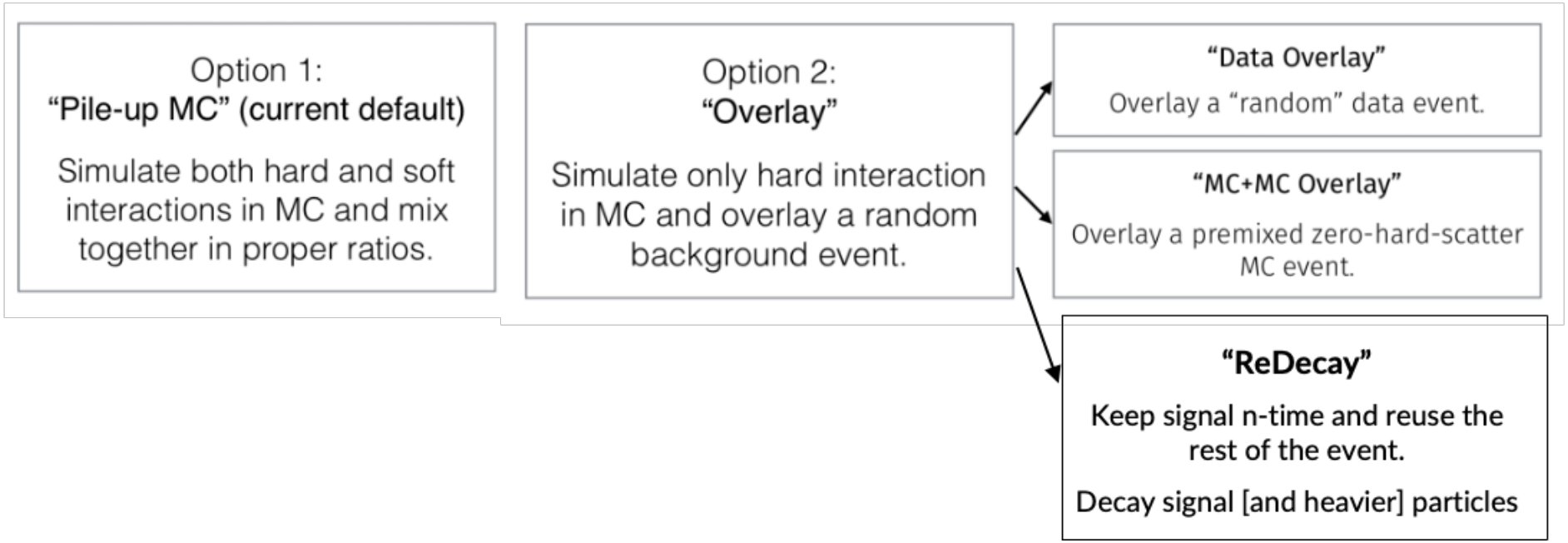
- Define a baseline for each sub-detector for refernce samples
- Each sub-detector can then provide a few alternatives

For different Run5 running configuration as defined by U2PG (geometry & detector conditions, beam & collision configuration/conditions, aka DataType) we need to setup production configurations

- Beam optics and luminosity – requires options file in AppConfig
- Which detector configuration we should use – requires options file in AppConfig and Detector project release and version of the geometry within, YAML conditions tags

Pile up

- Other collisions in current and additional bunch crossing
  - In the long term cannot keep the same implementation as we have (**no factor 10** in CPU pledges nor speed)

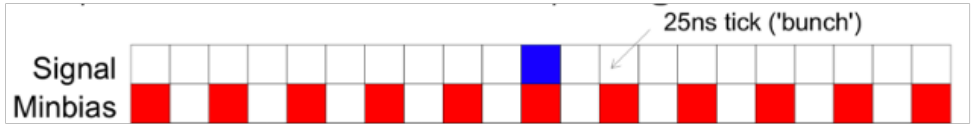


Built-in in Gaussino. Does it work for Run5 as-is?

Spill-over (aka out-of-time pileup)

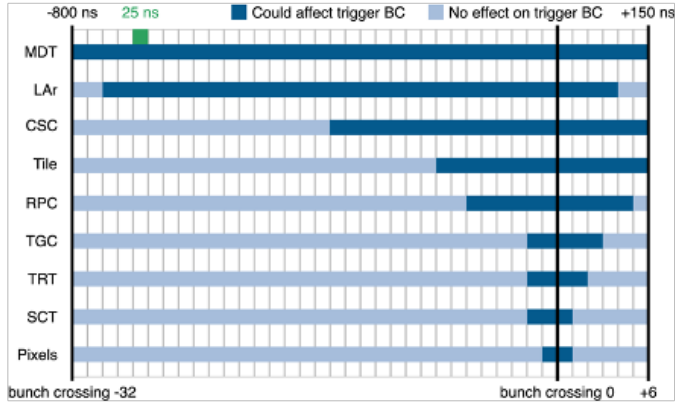
- Structure of filled and empty bunches needs to be simulated for higher pileup

Fixed 50ns spaced filled bunches



Train of 25 ns spaced bunches

- Sensitivity varies between detectors
- *(How) Do we need to worry about it in Run5 ?*
- Can use different implementations
  - Parametrisation
  - Partial simulations
  - Correlation between subdetectors introduce complexity



Simulation and Upgrade 2

- Private samples generated before Christmas
  - Putting together the MRs from VT, UP and MT for U2 tracking
  - RICH1 material included
  - Luminosity of 1e34

- Samples available
  - 250 Minbias events: /afs/cern.ch/work/m/mwhitehe/public/Gauss-30000000-250ev-20231219.sim
  - 1000 Incl b events: /eos/lhcb/user/m/mwhitehe/Gauss-10000000-1000ev-20231220_incb.sim
  - 250 Bs->Jpsiphi events: /eos/lhcb/user/m/mwhitehe/Gauss-13144001-250ev-20231221.sim

New samples

- Private samples generated after Christmas
  - Putting together the MRs from VT, UP and MT for U2 tracking
  - RICH1 material included
  - Luminosity of 1e34
  - BeamSpot4D included -> timing information should be available (MR 129!)
    - Bug fixed last night and moved interaction point to (0,0,0)

- Samples with timing available
  - 250 Minbias events: /afs/cern.ch/work/m/mwhitehe/public/Gauss-30000000-250ev-20240201.sim
  - 1000 Incl b events: /eos/lhcb/user/m/mwhitehe/Gauss-10000000-1000ev-20240201.sim