Physics impact of VELO timing

An impression of the VELO+CALO meetings' results

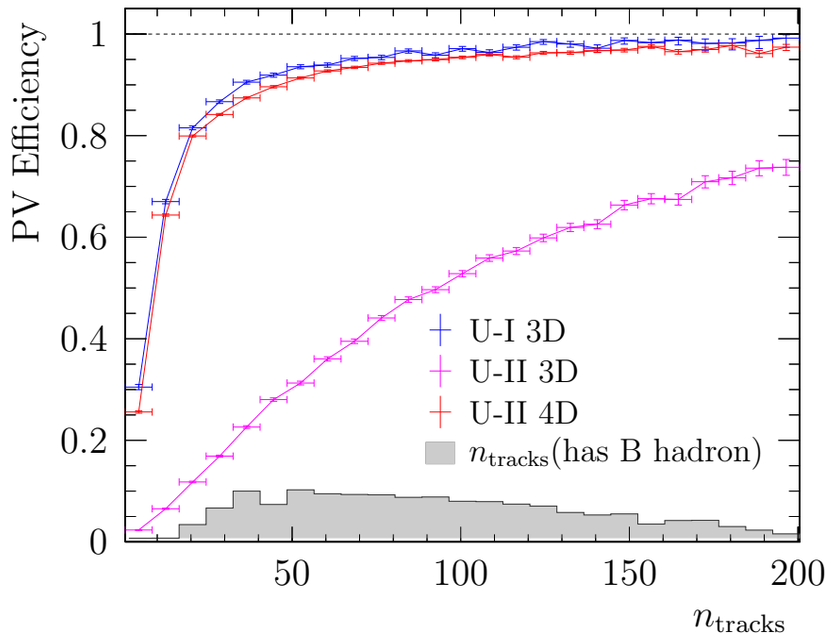
ECAL Upgrade-II Workshop December 13, 2022

Liupan An, Laurent Dufour, Tim Evans, Nathan Jurik, Philipp Roloff, Sascha Stahl,
and many others...

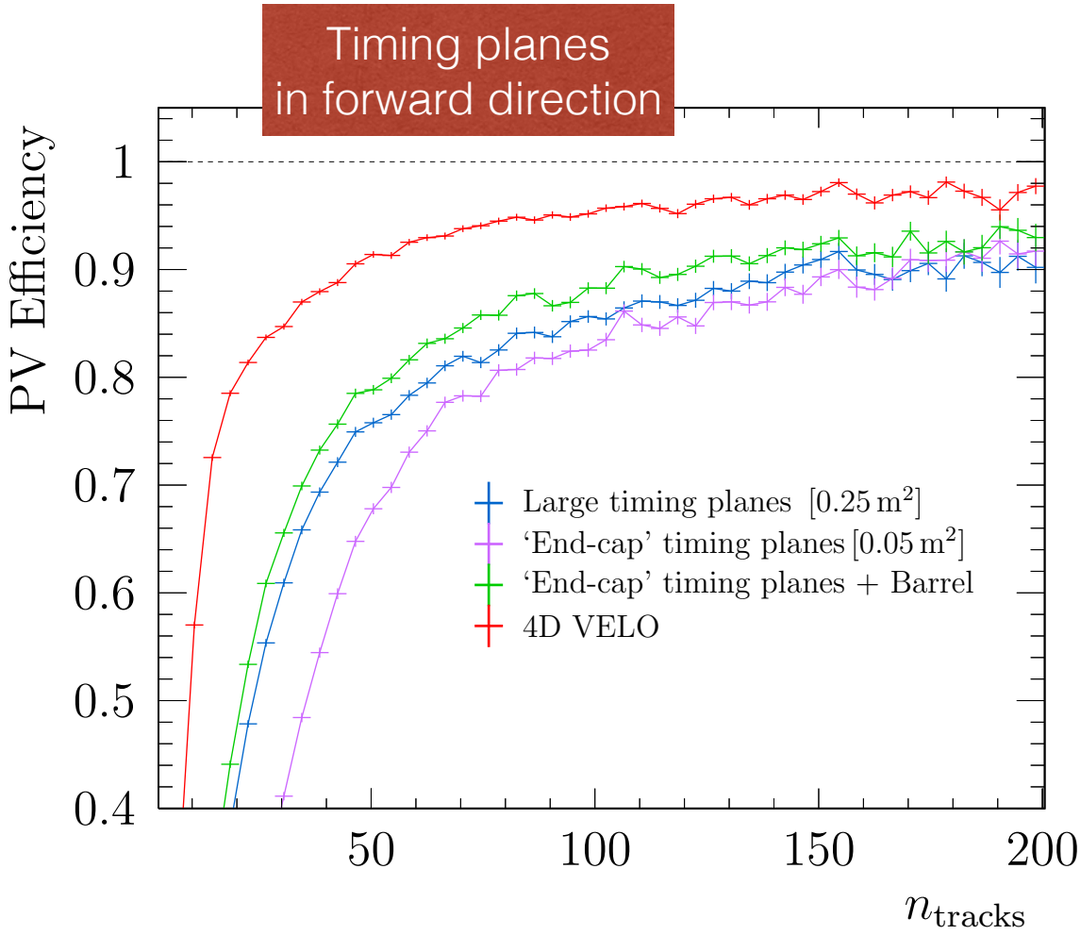
Introduction: VELO & timing

Physics studies: Upgrade-2 VELO needs to be a 4D detector, ~ 50ps/hit

Pattern recognition is helped a *bit*,
huge impact on vertex reconstruction



Timing planes
in forward direction



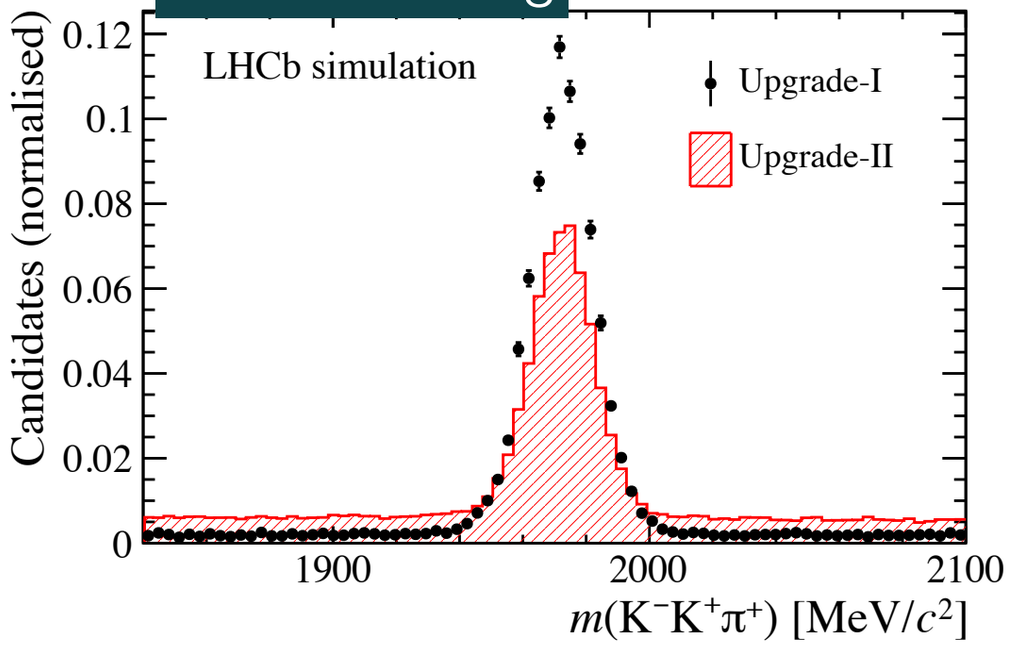
"timing planes" perform worse: to get even close to same performance, need barrel + forward + backward planes, with a maximum pitch of about 100μm

Perfect PID, 1% momentum resolution,
vertex detector track fit

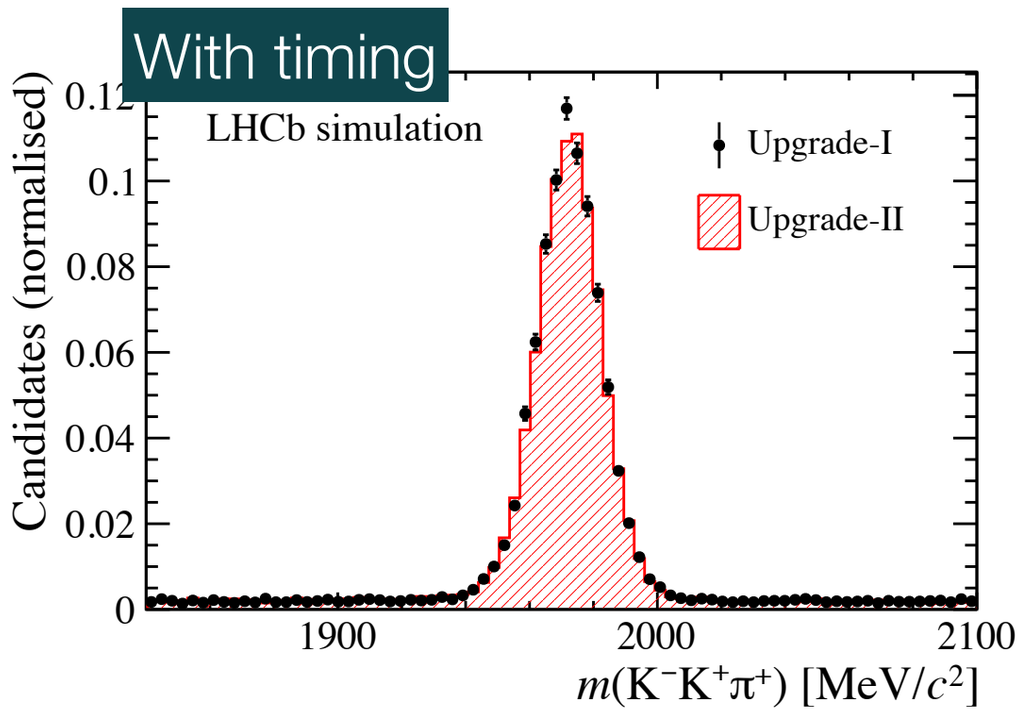
IP discrimination & combinatorics

Timing information not only relevant in **tracking**, but need to exploit to this in **selections** as well to get back to U-1 performance.

Without timing



With timing



Overall tracking & selection performance estimates needed to solidify clear case for global detector optimisation

VELO & ECAL

Timing information in the ECAL expected to originate from the VELO, but what with what resolution?

- ➡ How does this resolution depend on the kinematics, decay topology?
- ➡ How to deal with electrons, whose flight path is less certain by the bremsstrahlung?

Goal: optimise the combined parameters of the U2 timing in ECAL + VELO

Initiative last Summer: joint VELO + CALO meetings, open for everyone. **Technical nature** a space for people to discuss details efficiently.

Where did we start?

what will this detector do?

benchmark channels

Decay channel	Motivation
$B^0 \to K^{*0}\,\gamma$	Single photon
$B^0 \to K^{*0}\,\pi^0$	Merged π^0
$B^0 \to K^{*0}\,e^+\,e^-$	Bremsstrahlung & electron ID
$D^0 \to \pi^+\,\pi^-\,\pi^0$	Resolved π^0
Nobias & incl_b	Background (random / phys)
…	

first

Common event generation & simulation, rest of software stack

generation: move to same beam generator

simulation: use same .sim/.digi/.dst files to
(1) reconstruct tracks in VELO and (2) run the CALO reconstruction

[Tim Evans]

Luminosity decay

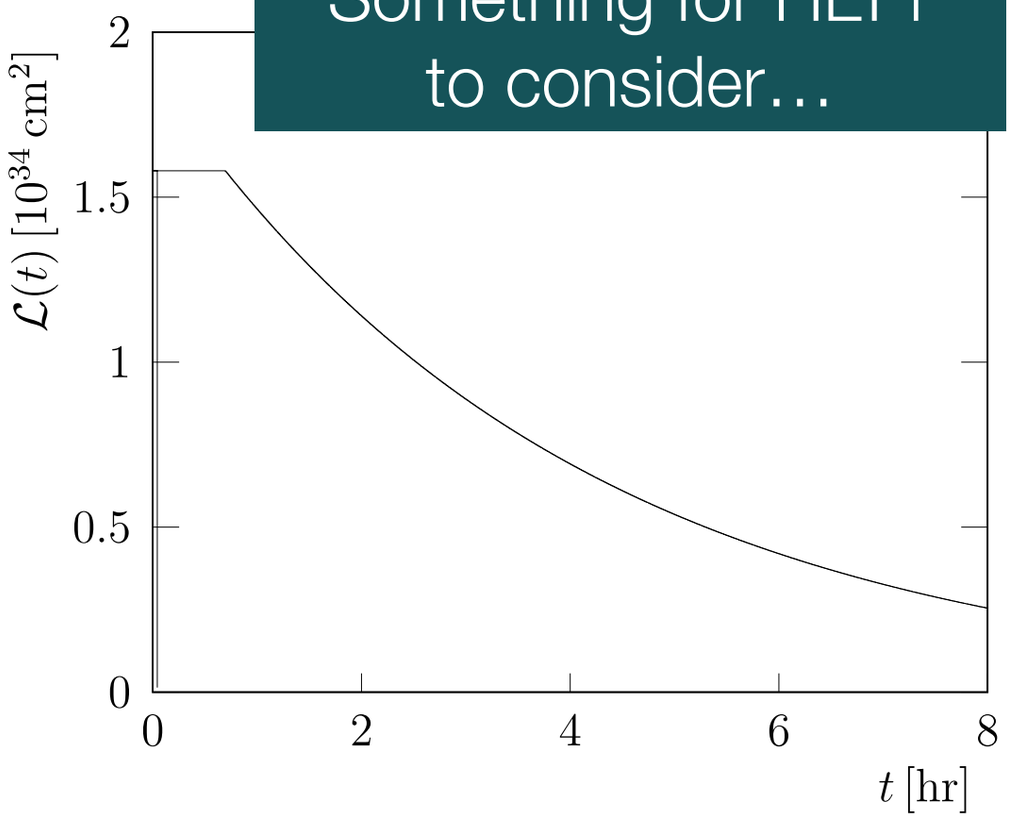
In Upgrade-2, the majority of the running time we will have our luminosity **not levelled**.Ideal world:

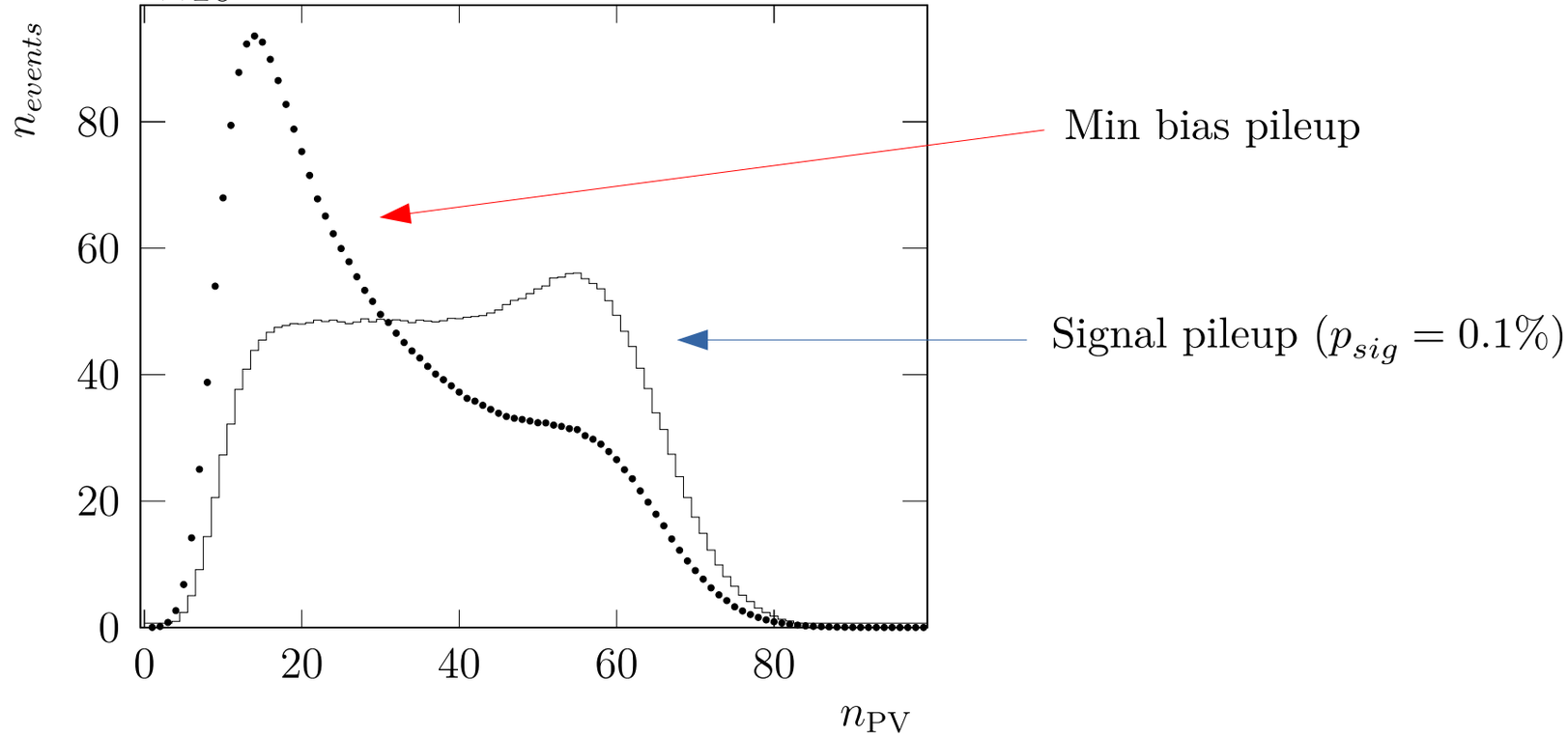
∂(physics performance)/∂t = 0,

not reality…

Makes sense to study performance for both t~0 & integrated

Something for HLT1 to consider…





With thanks to the simulation group

Simulation flow

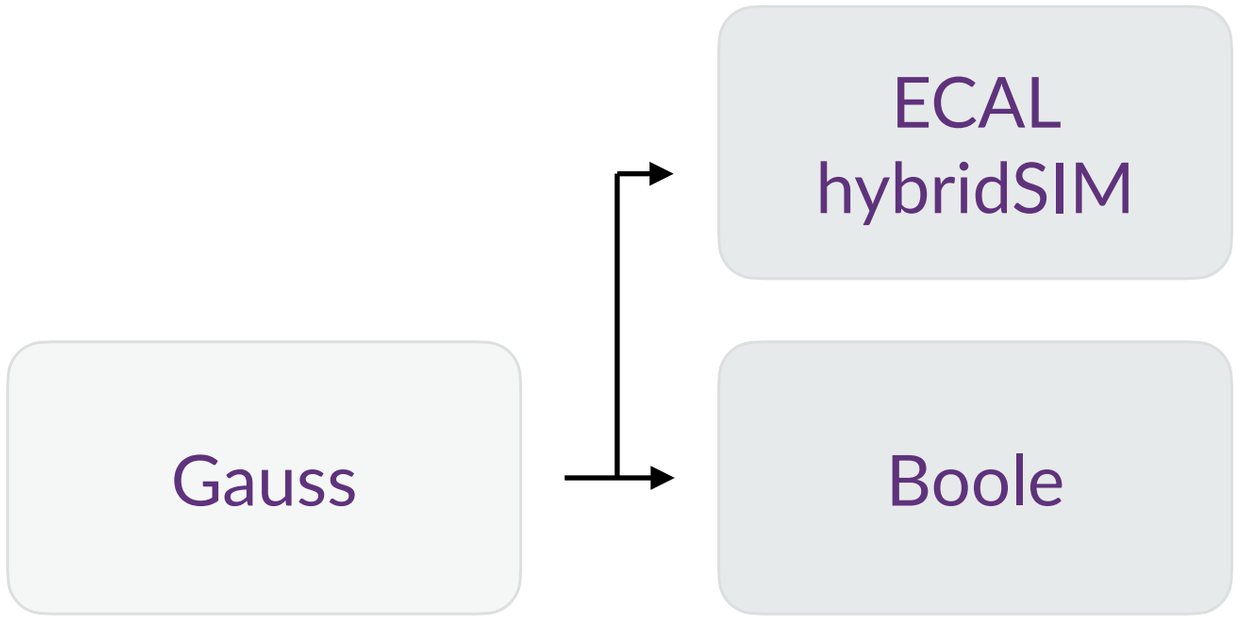
Gauss

Beam spot generation with BeamSpot4D & lumi decay

Detector geometry: Run 3
Can consider slight geometry variations (eg foil)

Run with full detector, ECAL implemented as '**ExternalDetector**':
large plane which collects all particles (neutral & charged) going through

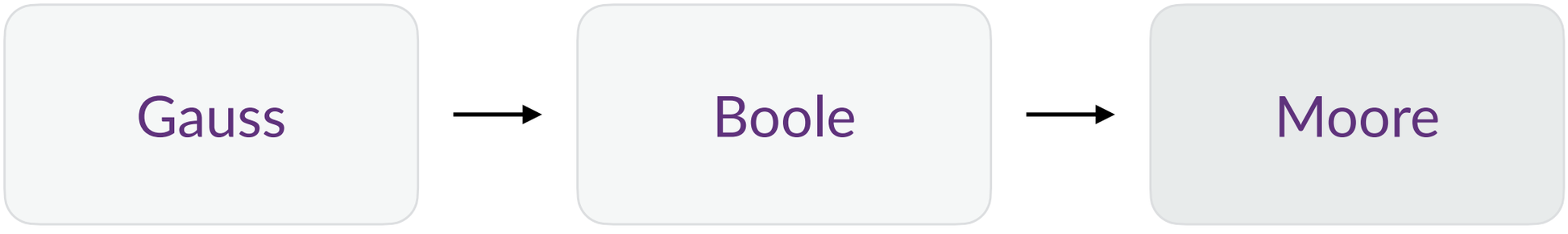
Simulation flow



Heavy “hybridSim” simulation per event run on a batch system

Fairly standard digitisation. Useful mostly for creation of ODIN raw banks (event number, run number).

Simulation flow

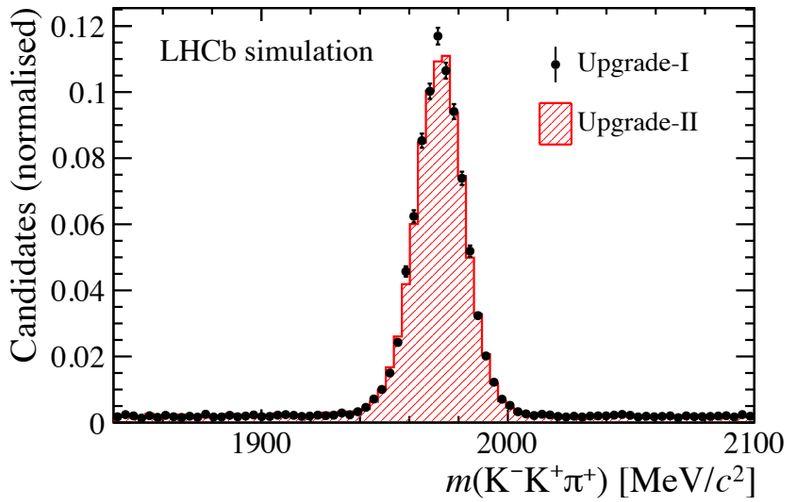


Moore: application for Track reconstruction, PV reconstruction, SV reconstruction & tupling / histogramming

Clusterisation of VELO done: spatial + time resolutions variable, option to scan the parameter space. **No worry about LHCbIDs**

Use a variation of the Run 3 standard VELO tracking (“SIMD”) that reads the clusters and can **use the timing on the hits.** Then run a Kalman filter to prepare the tracks for fitting PVs in space + time.

Simulation flow

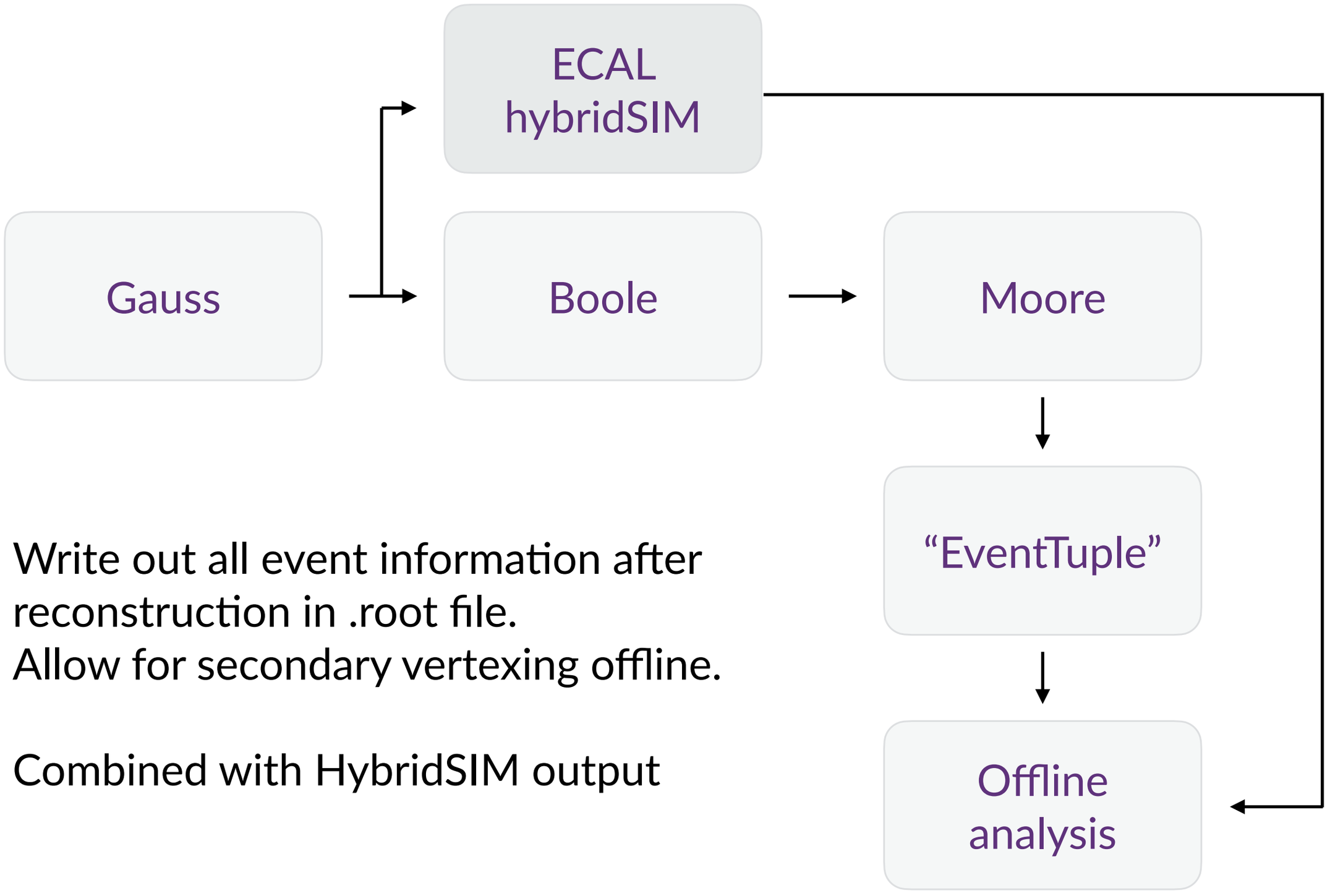


Gauss → Boole → Moore

Fake long tracks:

All VELO tracks in the forward acceptance upgraded to “long” tracks: ∂p/p = 0.5% for tracks matched to MC particles (those not matched, still upgraded). Track fit reran.

Simulation flow

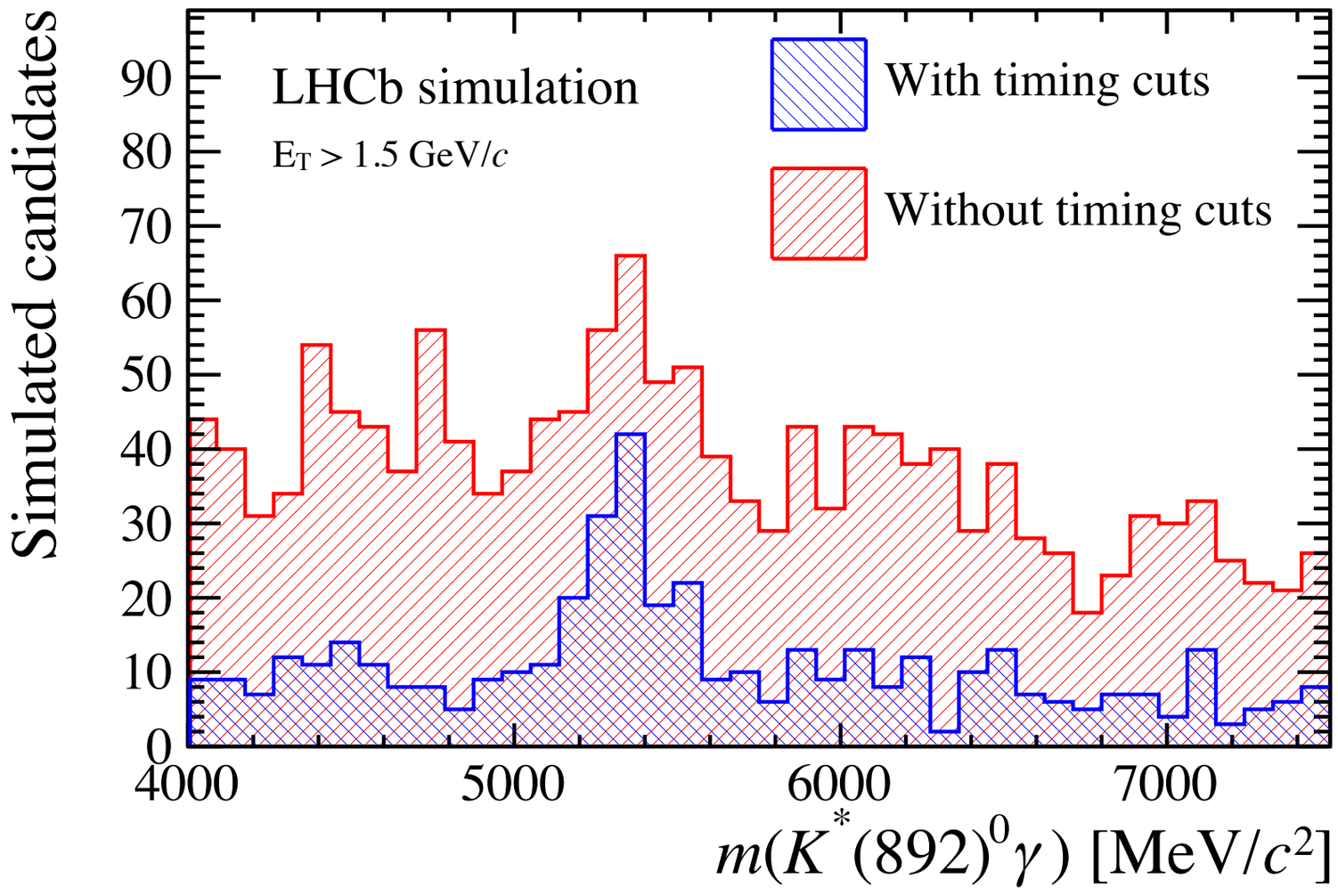


Write out all event information after reconstruction in .root file.
Allow for secondary vertexing offline.

Combined with HybridSIM output

Thanks to Liupan An, Philipp Roloff, Tim Evans for last-minute work for this workshop

… a look at a first result



Timing cut:
$\Delta t < 3\ \sigma$

- ✓ Sample generated with luminosity decay
- ✓ Timing of K* vertex coming from VELO detector (4D tracking)
- ✓ Timing of photon from detailed SPACAL simulation

Conclusion

First steps to the multidetector, global optimisation of the Upgrade-II detector design made, and clearly a long way to go

Have *just now* the tools at hand to generate samples and perform scans as a function of detector resolutions, position, and signal kinematics

Aim to explore what we can get out of this setup before Barcelona WS, and then focus on further **integration in standard LHCb productions**.

Hope to include other trackers when they feel ready…

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