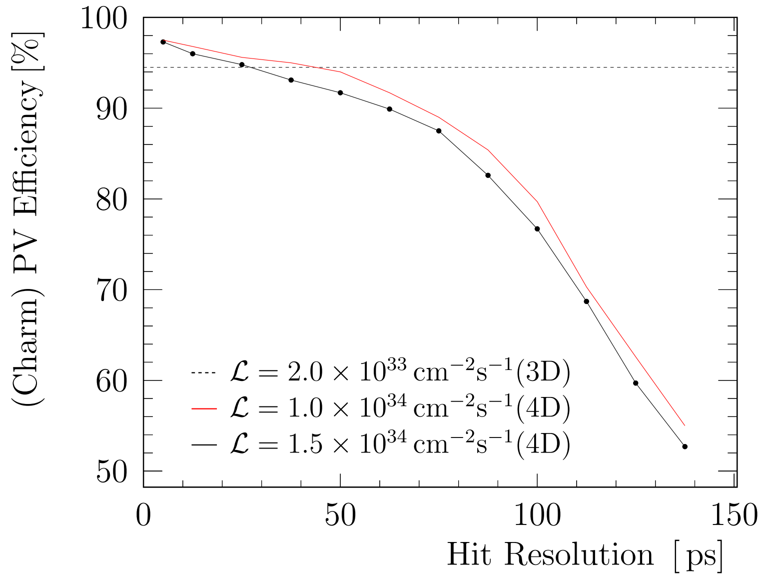
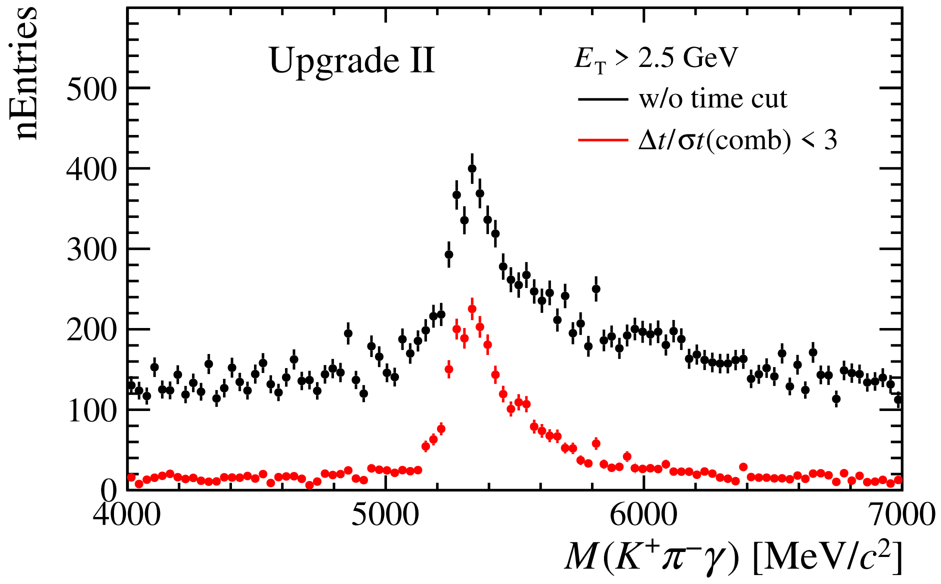
Time Resolution Optimisation: A joint Velo/Ecal Simulation

Liupan An, Laurent Dufour, **Tim Evans**, Nathan Jurik, Philipp Roloff & many others

VELO



ECAL



$\sigma_t \sim 10 \rightarrow 20\,\mathrm{ps}$

This can be addressed by transforming the VELO to a true 4D-tracking detector, adding timing information with a precision of better than 50 ps. This will allow to provide a time stamp on each track with a precision of 20 ps allowing standalone selection of displaced tracks or parts of events (such as individual PVs)

[From LHCb TDR 23]

VELO+ECAL FOR UPGRADE II

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$\implies$ Joint studies between VELO and ECAL groups

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- Need to look at specific physics channels to look at performance between multiple detectors.

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$B^0 \to K^* \gamma$	Single photon
$D^0 \to \pi^+ \pi^- \pi^0$	Resolved π^0
$B^+ \to K^+ \pi^0$	Merged π^0
$B^+ \to K^+ e^+ e^-$	Electron ID & Bremsstrahlung

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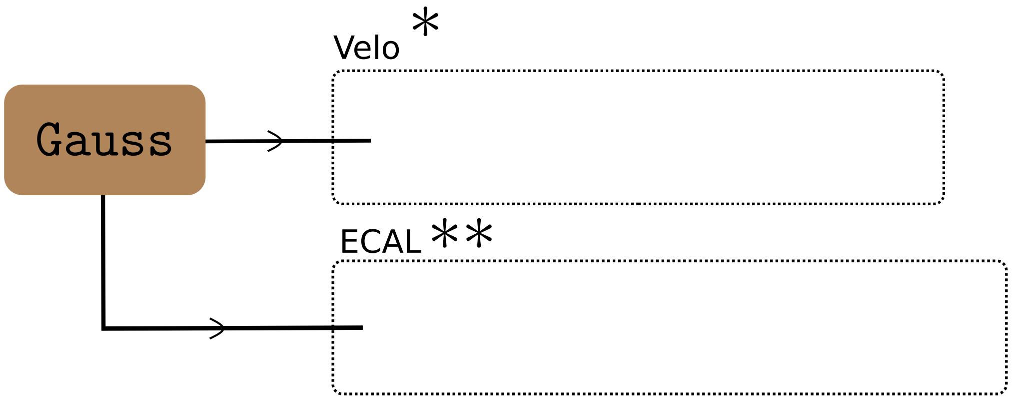

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- Upgrade I ‘Scenario A’ geometry

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- Use Gauss to simulate particles traversing the detector up to surface of the ECAL
- Replace the ECAL with an `ExternalDetector` (∼ plane that collects the MCparticles)

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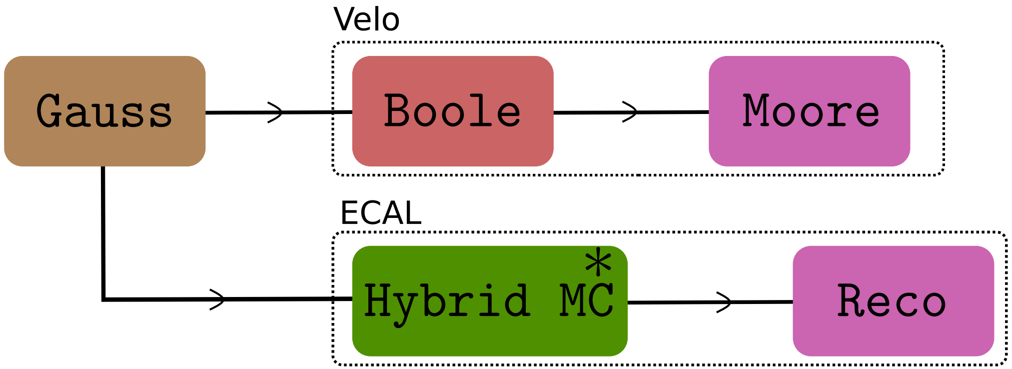

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- Uses Geant4 for energy deposition / propagation of Cherenkov photons
- Parameterised propagation of scintillation photons in the fibres to the PMTs
- Default simulation would be $\sim$ hundreds $\times$ slower
- Still takes around $15s/$ GeV to simulate
  (typical energy in ECAL in U2 event $5 \rightarrow 10$ TeV)

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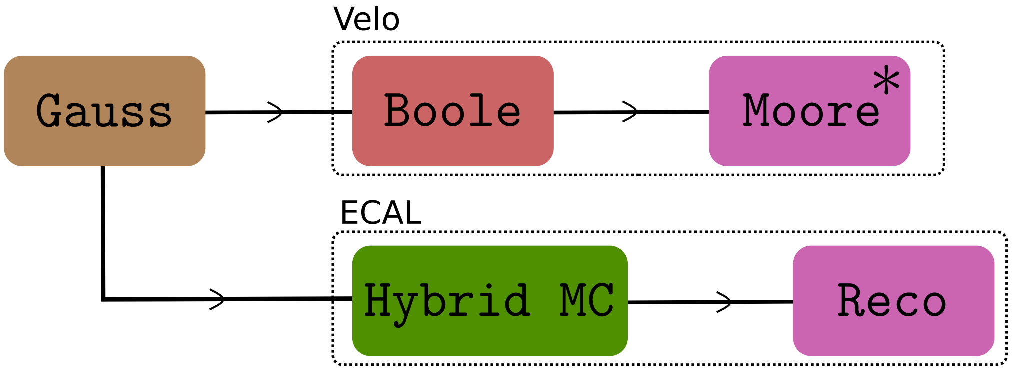

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- Full Velo Reconstruction
- Fake long tracks (assume $\Delta p/p = 1\%$)
- Assumes perfect PID

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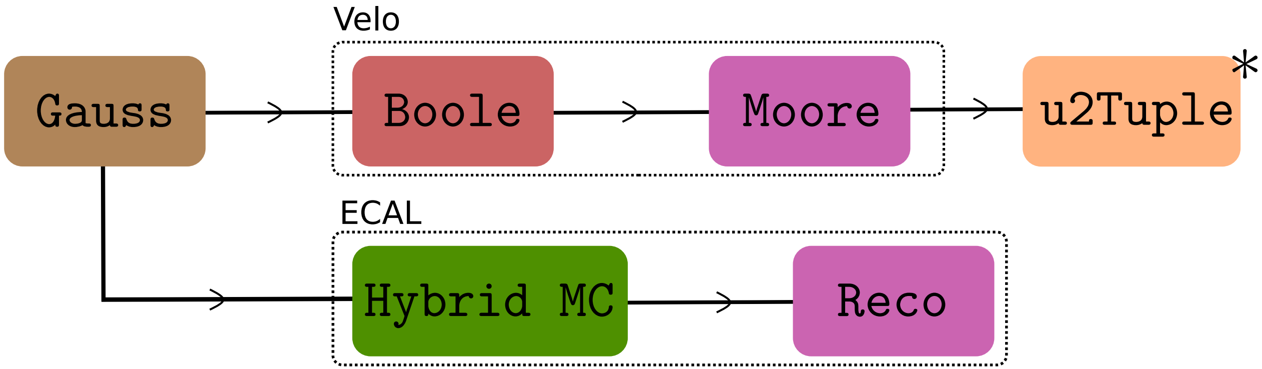

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- Provides basic tools for selections in presence of lots of PVs
  - $IP, \chi^2_{IP}, ...$
  - IP_t, χ^2_{IP-4D}
  - Secondary vertex fitting

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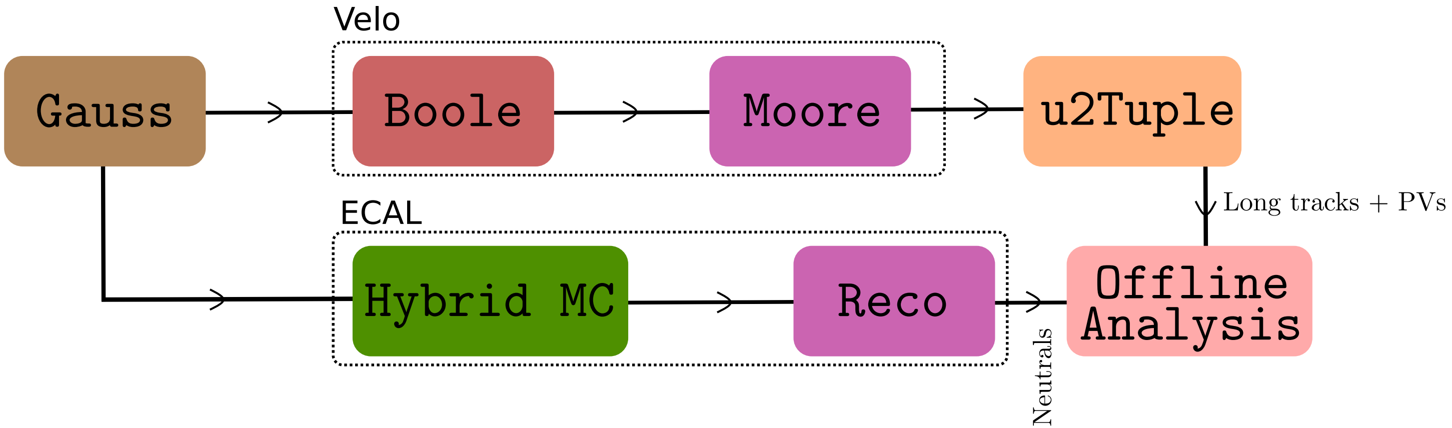

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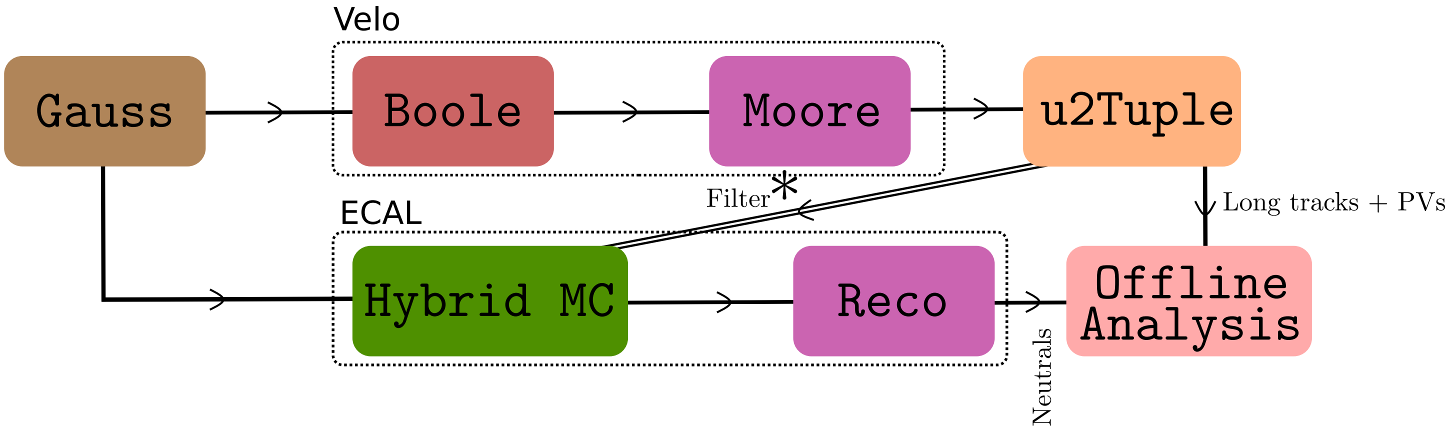

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- Can filter on reconstruction / selection of the charged part of decay, *i.e.* for $B \to K^*\gamma$, require we reconstruct a good K^*
- Essential due to the CPU cost of the ECAL simulation
- Preferred to generator cuts as can also use on background samples.
- Is going to be absolutely essential for charm physics where $\mathcal{O}(\varepsilon_{\text{filter}}) \sim 1\%$

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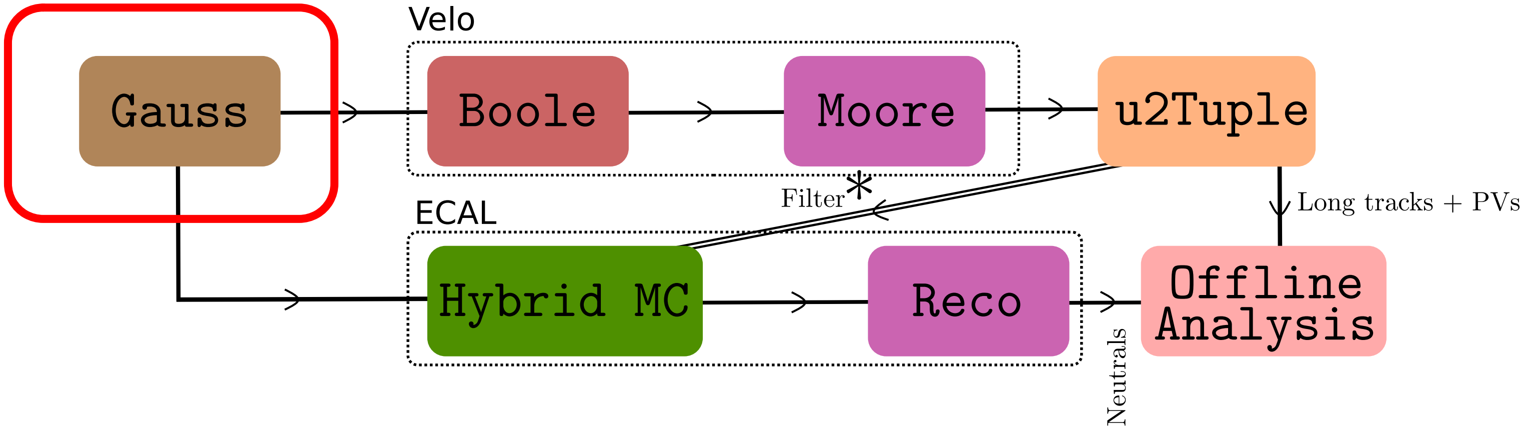

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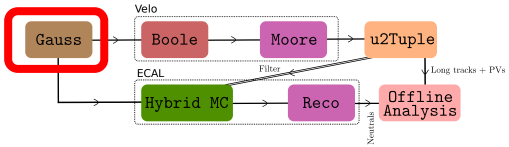
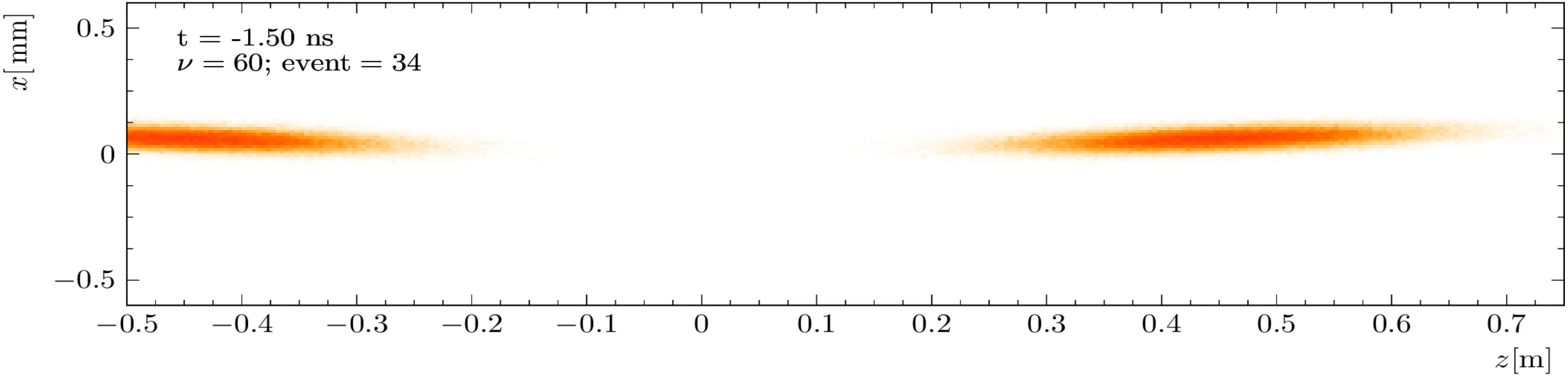
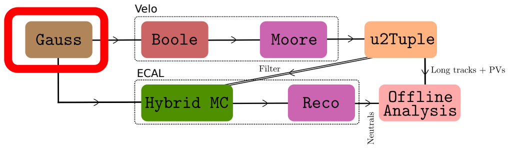
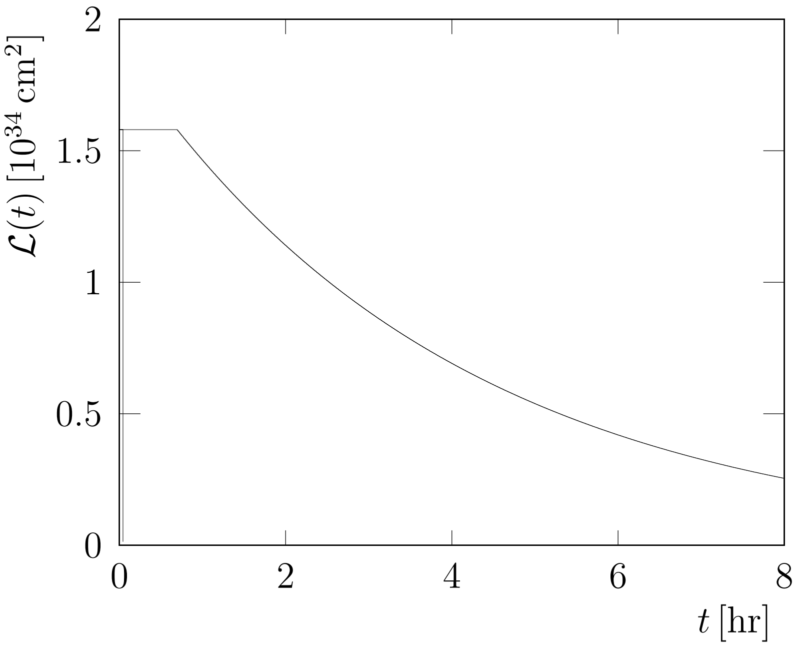




- Common luminosity definition / generation using `BeamSpot4D`
  - $\nu_{peak} \sim 60$
  - $\sigma_t = 180\,\text{ps}$
  - $\sigma_z \sim 45\,\text{mm}$

Aside on pileup





Effectively no longer a levelled experiment!

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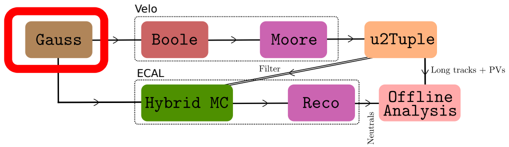
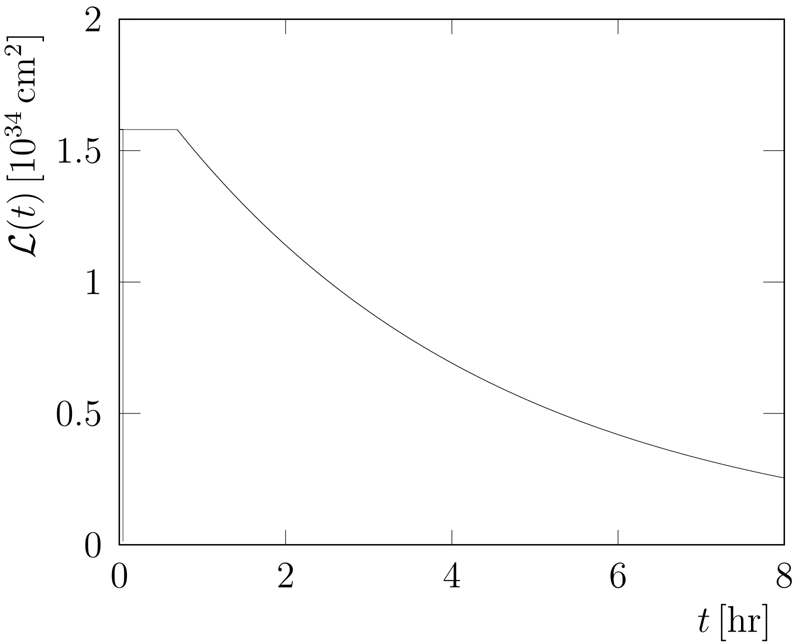
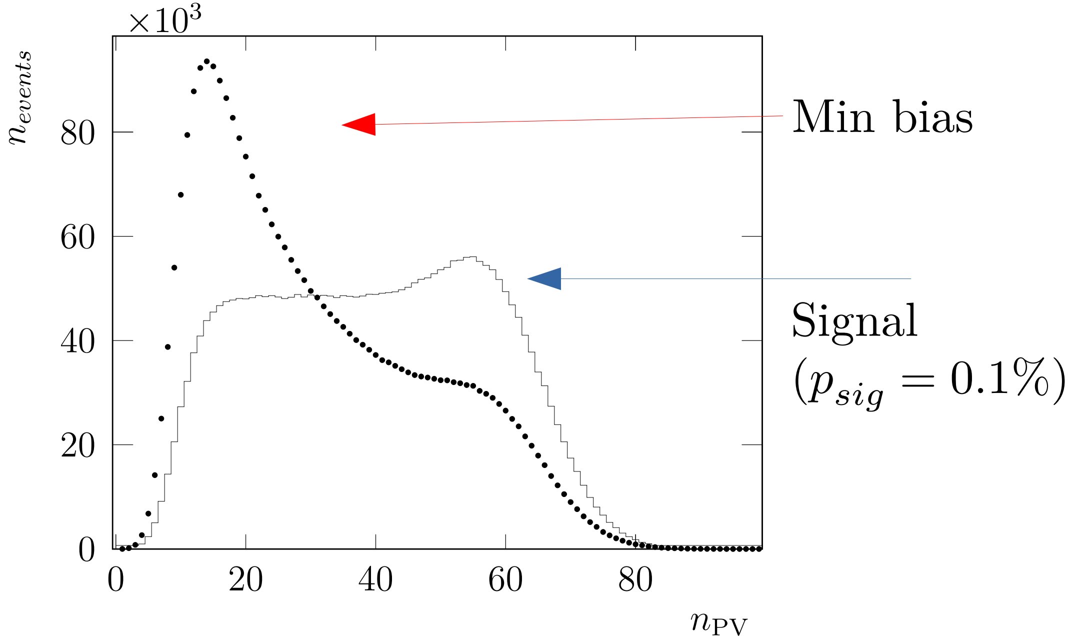






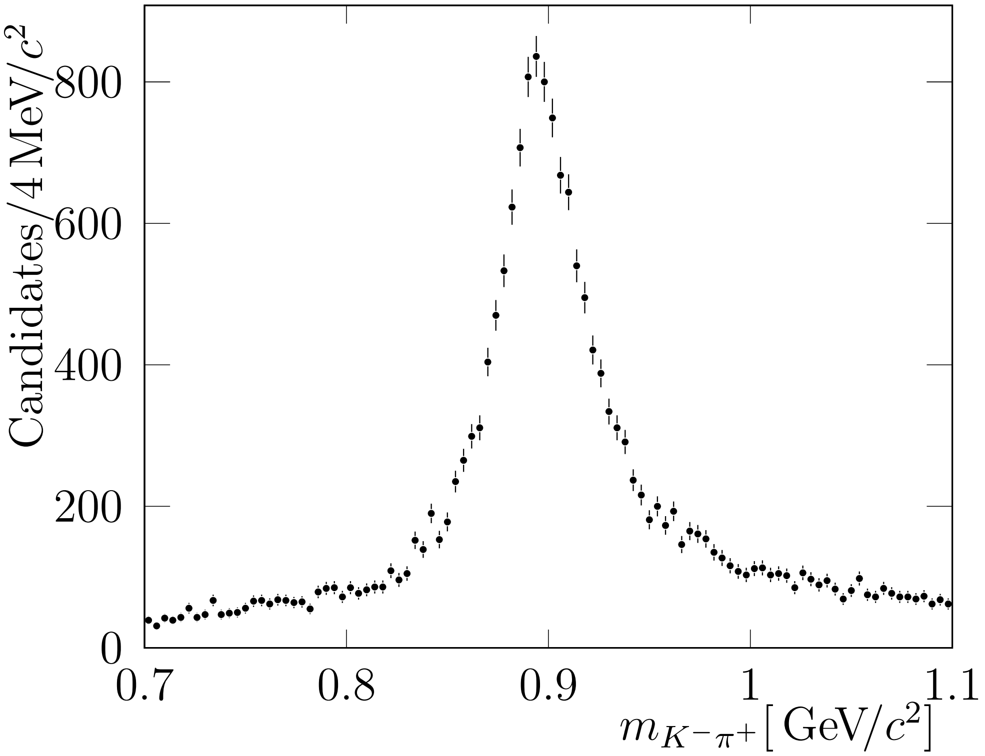
Simulate the decay of the beam (implemented in Gauss)

- Needed for physics/HLT2-like studies

$B \to K^*\gamma$

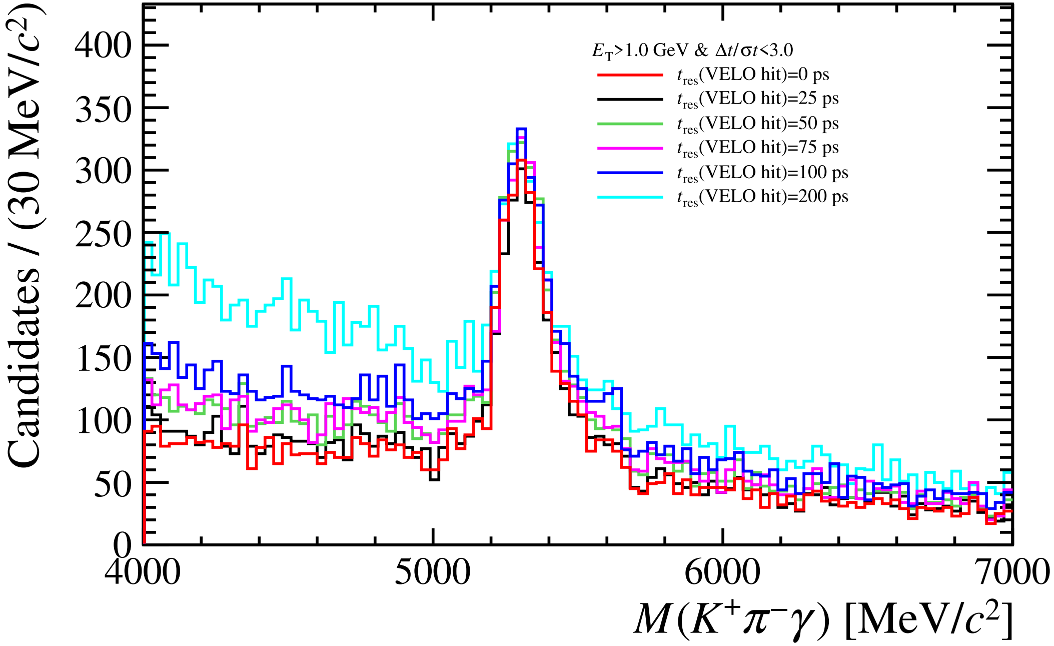
- Select with a lot of the same tools* as Run 1/2/3 selections:
  - $\tilde{\chi}^2_{IP}$, p_T
  - DIRAs + timing cuts
  - vertex χ^2 distance
- Relatively clean sample of displaced K^*

  $\implies$ But still very preliminary selection!
- Background mostly from heavy flavour!



* sometimes with 4D variants

$B \to K^*\gamma$

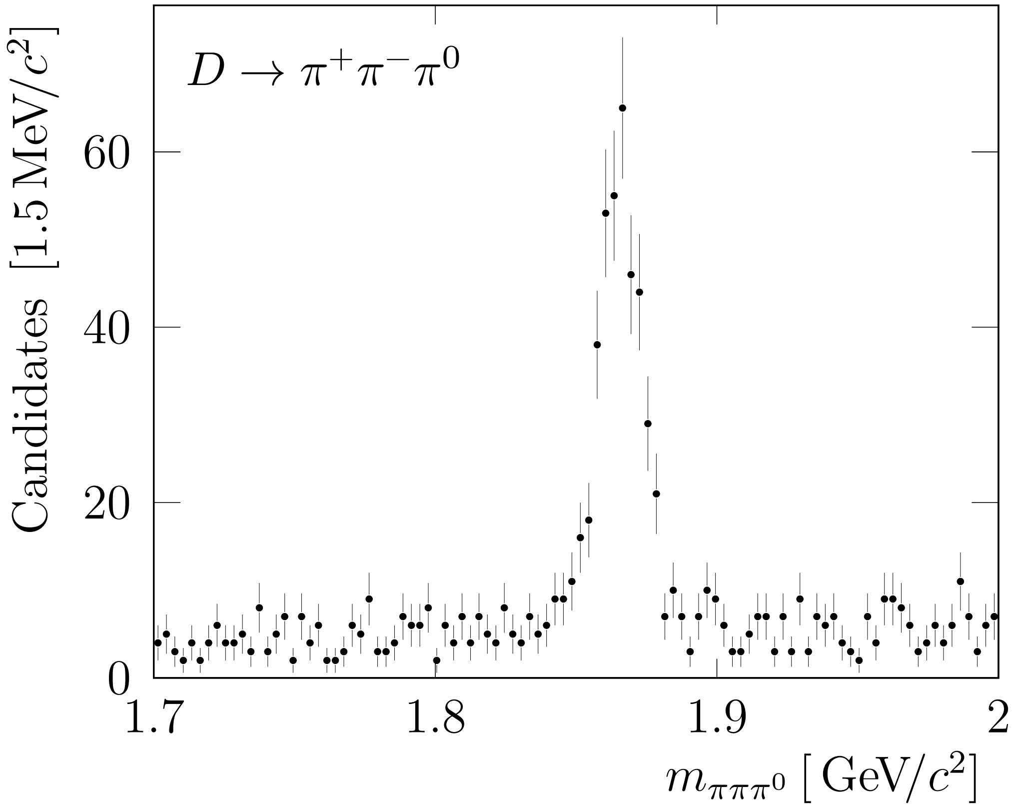


- Combine K^* candidate with high E_T photons within 3σ time window
  - Study matching as a function of VELO time resolution
  - Clear degradation in purity as a function of t_{res}
  - Significant degradation in efficiency at poor time resolution
- Selection is very preliminary

  $\Longrightarrow$ Not yet ready to make quantitative conclusions

Next steps

- Work towards more realistic selections
- Simultaneous look at VELO vs ECAL resolutions
- First look at $D^0 \to \pi^+\pi^-\pi^0$
  - Entirely fake the π^0 using MCparticles
  - Still to see how well π^0 reconstruction works in these conditions ...
  - Very challenging, *even with fake* π^0, but not entirely impossible!
- Possibility to look at (approximate) impact of other scenarios, beyond only time resolution
- Try to understand *when* in the fill signal and background is coming from.



Some final thoughts ...

- A lot of the groundwork for doing global optimisation has been done here

  $\Longrightarrow$ Targetting global studies for the scoping document (next year)

- **And** has been extremely useful in solidifying the requirements for both detectors

But
  - Pairwise collaboration between projects doesn't scale well to the whole experiment ...
  - Ultimately, everything will move towards running within LHCb code.

Pragmatically, if subdetectors need reconstruction-level information from the VELO, we can repeat parts of the workflow used here.