Optimization of HLT2 selections at the LHCb experiment

Daniel Magdalinski
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About me: Daniel Magdalinski

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- Both bachelor and master at Lund University

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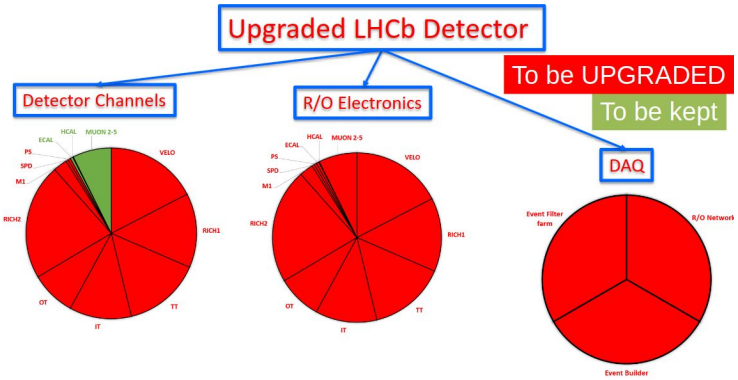
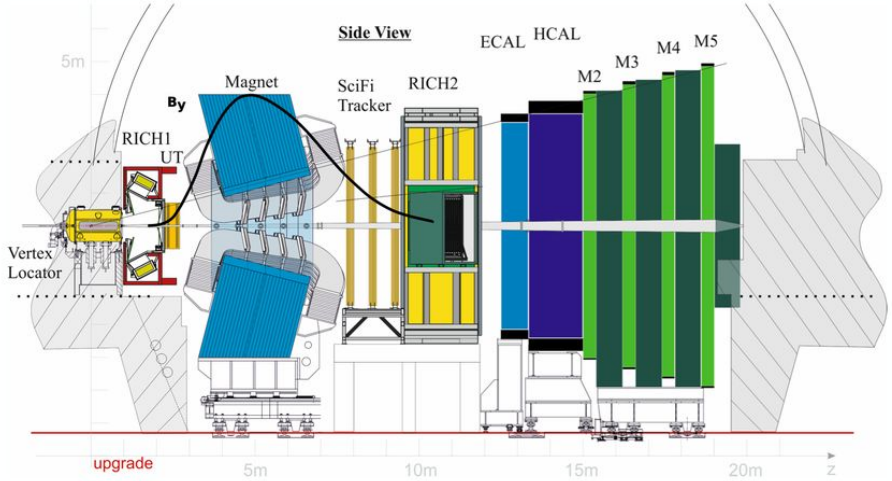
- CERN Summer Student 2022
- Now: ESR6 in Amsterdam since October 2022
    - Optimization of HLT2 trigger

LHCb experiment

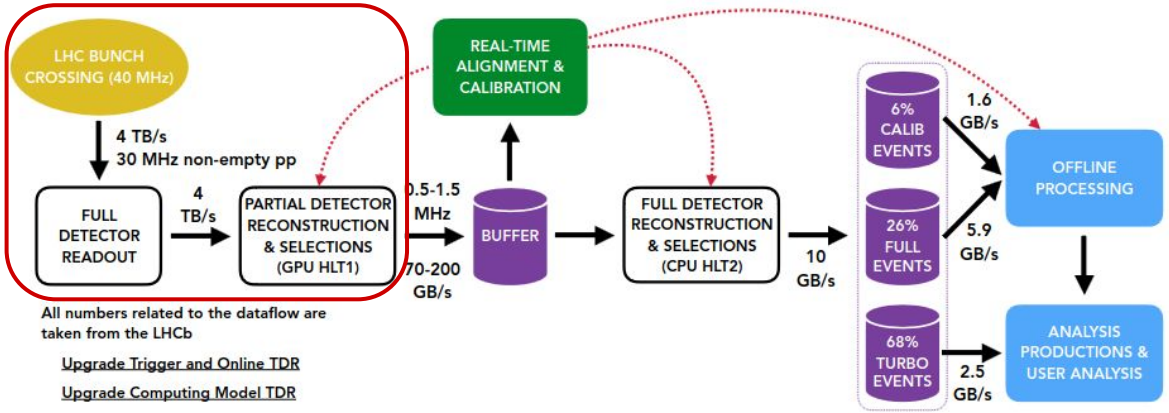
- Forward spectrometer designed for flavour physics through beauty and charm decays
- Detector upgraded for Run 3 to handle increased luminosity
  - Changes to nearly all subsystems
- Flexible full-software trigger system enables a more general physics program





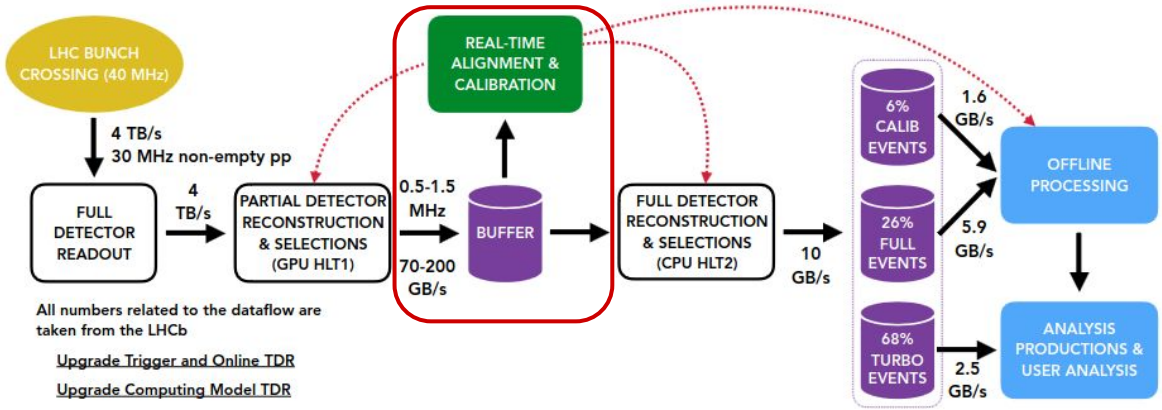
LHCb Run 3 trigger

- 30 MHz and 4TB/s of detector read-out → 10 GB/s data storage
- HLT1:
  - GPU-based algorithms focused on tracks, displaced decay vertices and muons



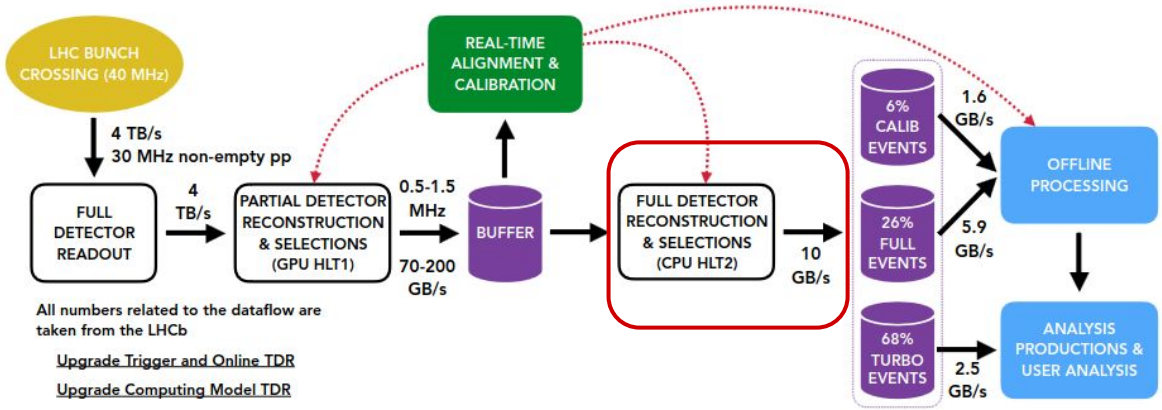
LHCb Run 3 trigger

- 30 MHz and 4TB/s of detector read-out → 10 GB/s data storage
- HLT1:
  - GPU-based algorithms focused on tracks, displaced decay vertices and muons
- Alignment & Calibration
  - Event buffer between HLT1 and HLT2
  - Real-time alignment and calibration giving offline-level reconstruction to HLT2



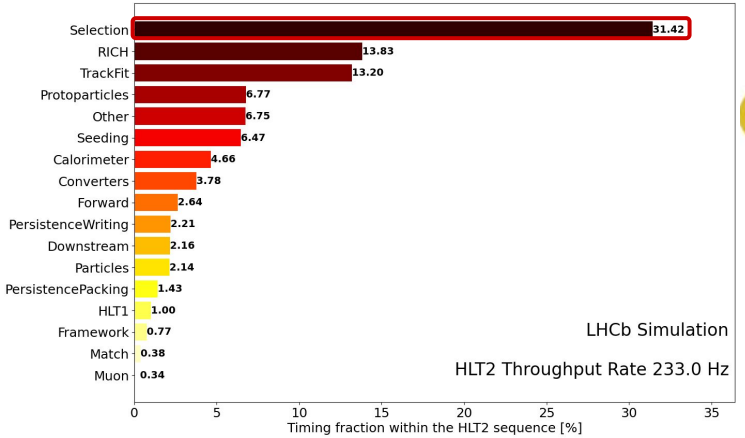
LHCb Run 3 trigger

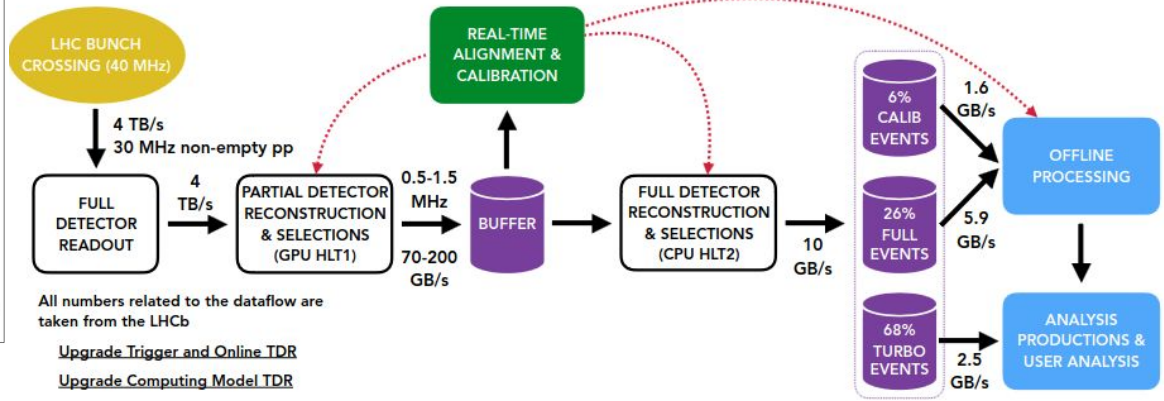
- HLT2:
  - Reconstruction and selection of physics objects for analysis through trigger lines



LHCb Run 3 trigger

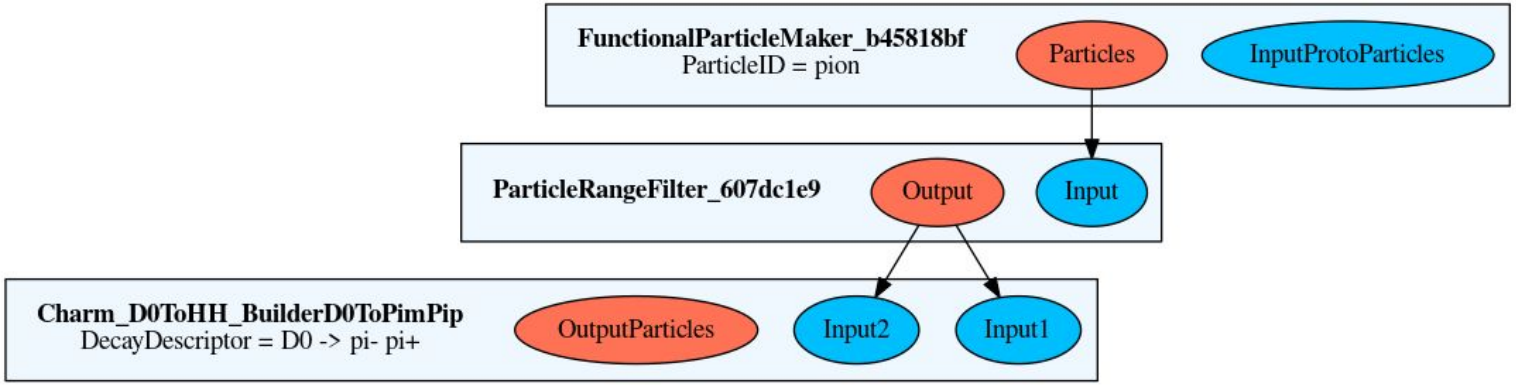
- HLT2:
  - Reconstruction and selection of physics objects for analysis through trigger lines
- Selections: ~30% of HLT2 computing cost
  - Fraction growing as new lines are added





HLT2 trigger selections

- ~2400 trigger lines currently written
- Line is a collection of selection algorithms
- Lines usually consists of at least
  - Maker: Creates a container of particles coming from reconstruction
  - Filter: Performs cuts on input particles
  - NBodyCombiners: Iterates over combinations of N input particles and performs cuts on combination



Can become quite complicated

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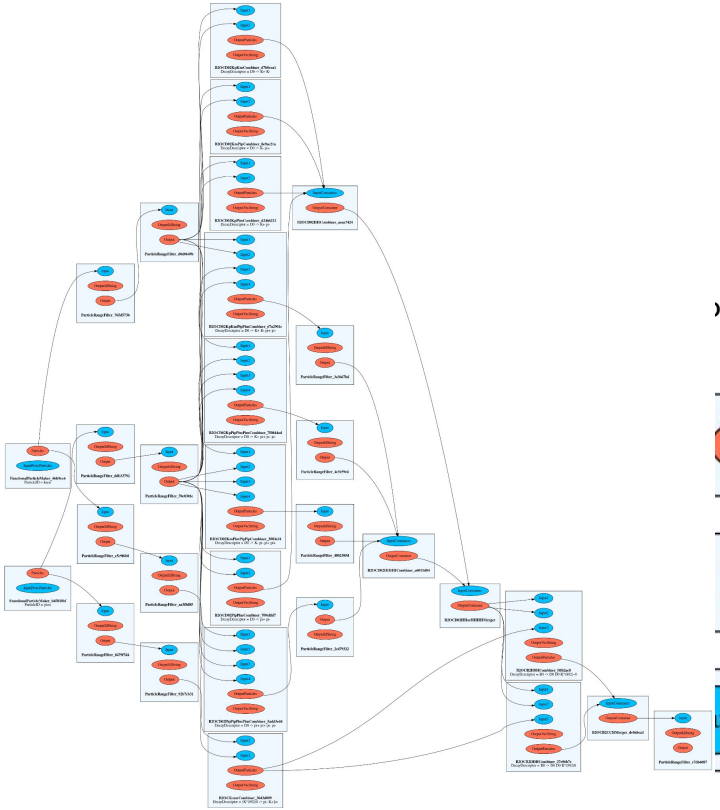
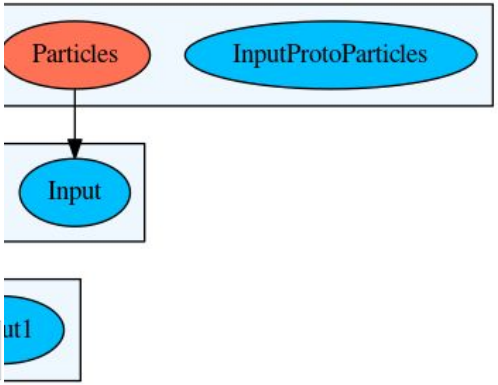
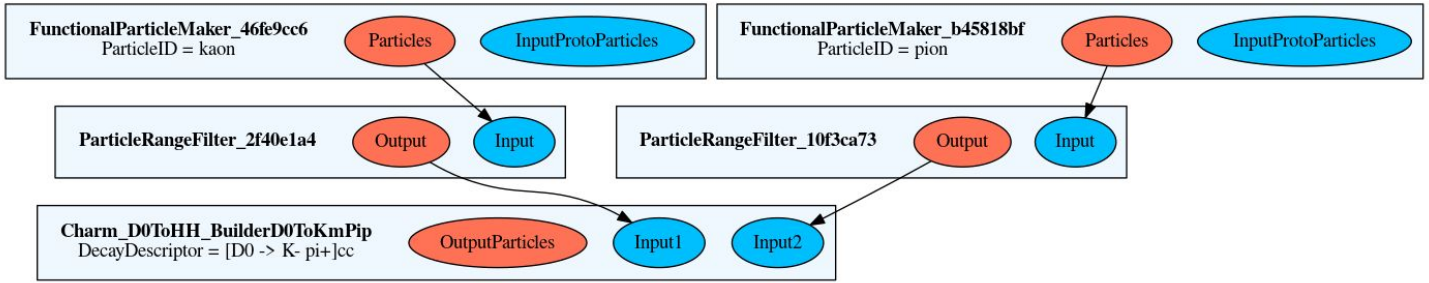




Charm_D0ToHH_Build
DecayDescriptor = D

HLT2 trigger control flow

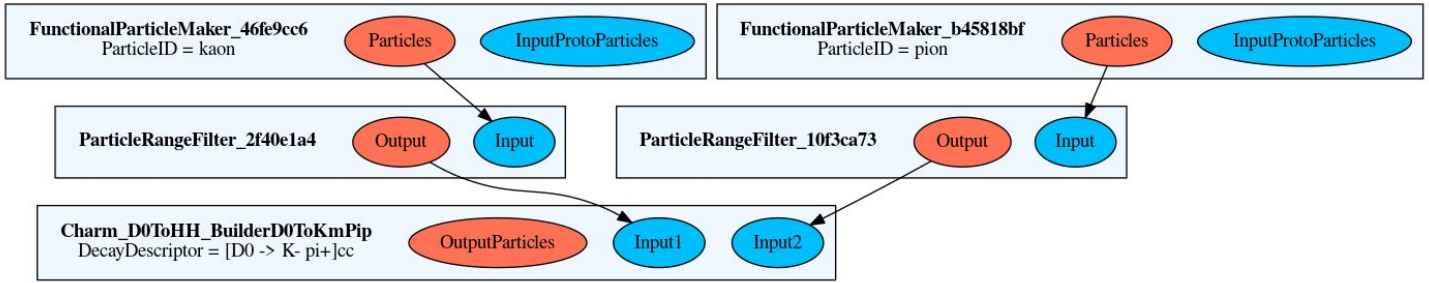
- Control Flow optimization
  - Data flow: The data dependence of trigger line algorithms



HLT2 trigger control flow

- Control Flow optimization
  - Data flow: The data dependence of trigger line algorithms
  - Control flow: Which algorithm(s) that decide if the line triggers
    - Can be a list of algorithms to perform early stopping

```python
@register_line_builder(all_lines)
def dzero2kpi_line(name='Hlt2Charm_D0ToKmPip', prescale=1):
    kaons = make_charm_kaons()
    pions = make_charm_pions()
    dzeros = make_dzeros(kaons, pions, '[D0 -> K- pi+]cc')
    return Hlt2Line(
        name=name, algs=charm_prefilters() + [dzeros], prescale=prescale)
```



HLT2 trigger control flow

- Control Flow optimization
  - Data flow: The data dependence of trigger line algorithms
  - Control flow: Which algorithm(s) that decide if the line triggers
    - Can be a list of algorithms to perform early stopping
- Optimization approach
  - Test run for statistics on how often an algorithm outputs
  - Iterate through data flow
  - Add rarest algorithms to control flow

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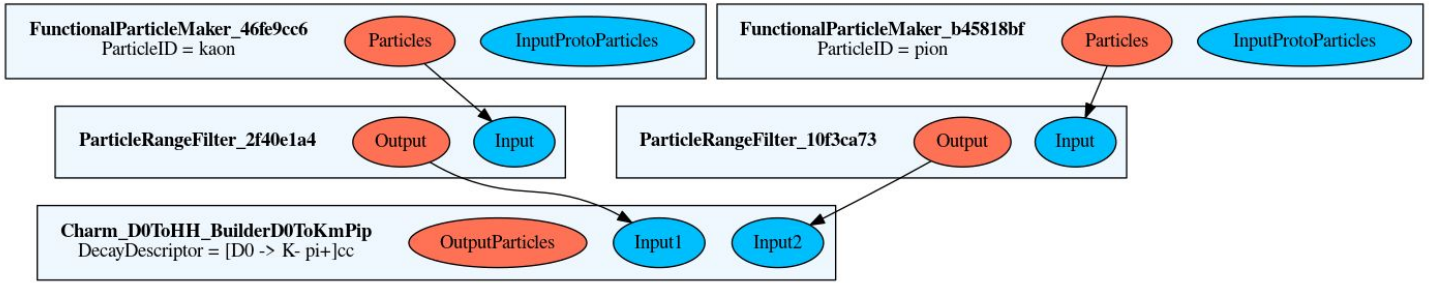
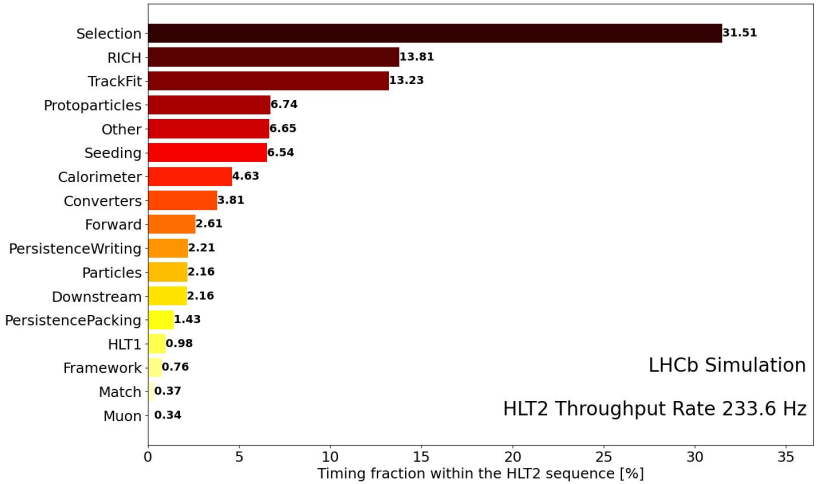
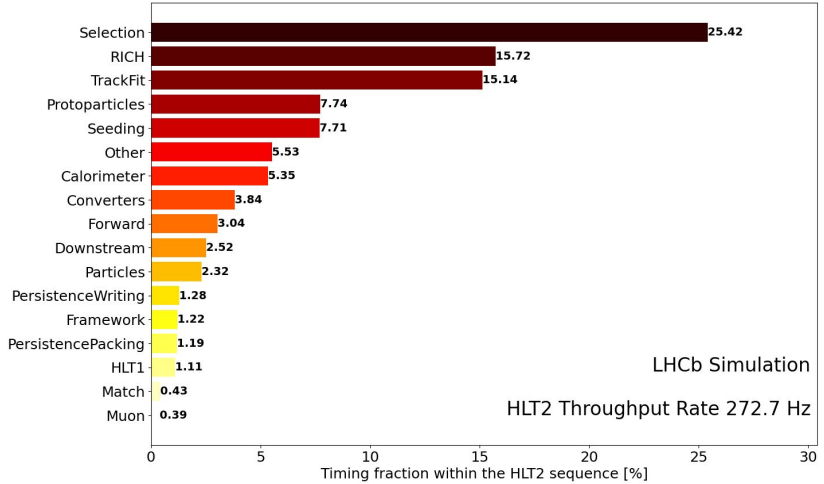


Control flow results

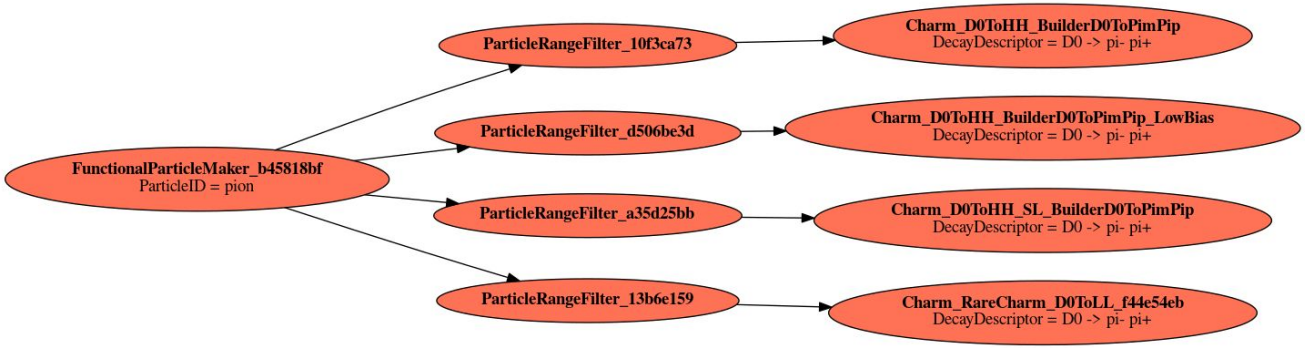
- Performance CI-test
  - 20000 minimum bias events
  - Isolated environment at CERN
    - Similar to trigger operations
- Throughput rate improved by 16.7%
  - Thorough checks into throughput agreement under way





HLT2 combiner optimization

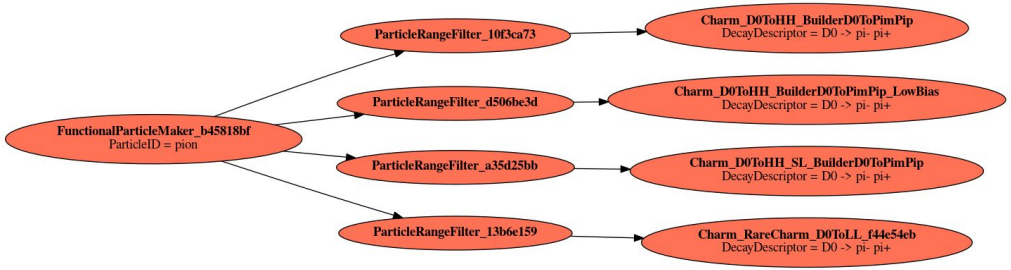
- Problem: Trigger lines might perform very similar operations
  - Tiny differences creates duplicate algorithms
- Goal: Identify and combine overlapping algorithms
  - Timing gains
  - Potential storage gains: Reducing duplicate particles
- Different setup, ~1500 lines



Combiner optimization

- Optimization
  - Identify combiners with common grandparent

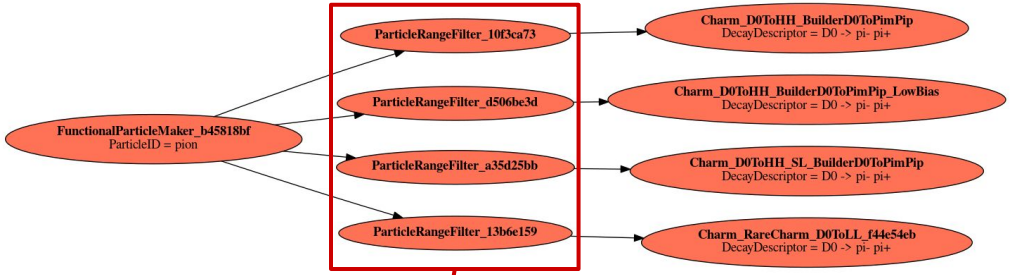
- Old:



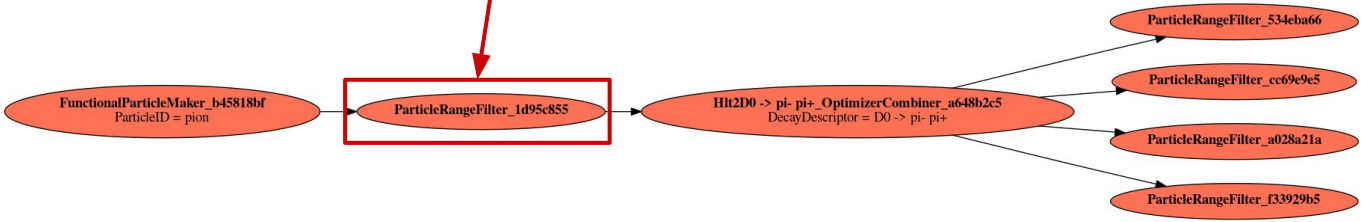
Optimization framework

- Optimization
  - Identify combiners with common grandparent
  - OR operator applied to cuts
  - Separation into original containers

- Old:



- New:



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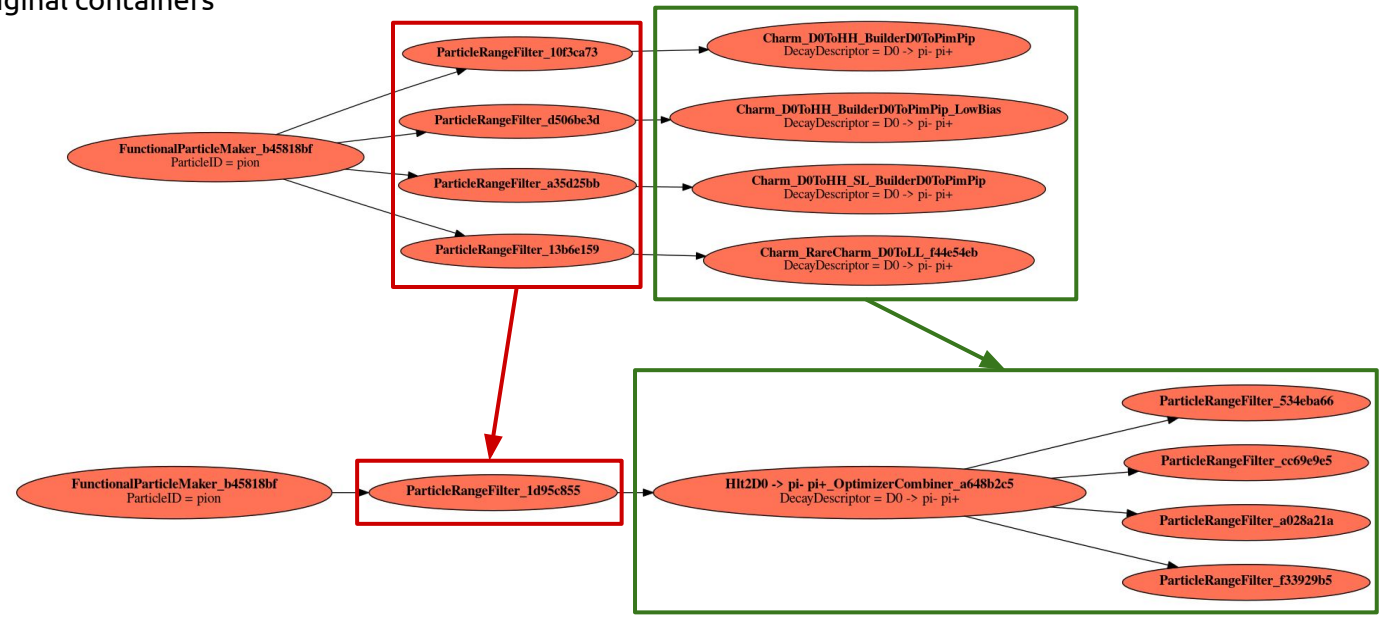
- New:



Initial performance

- Initial performance
  - 134 sets
  - ~500 combiners
  - ~1100 lines affected
- Naive combination
  - Full set always combined

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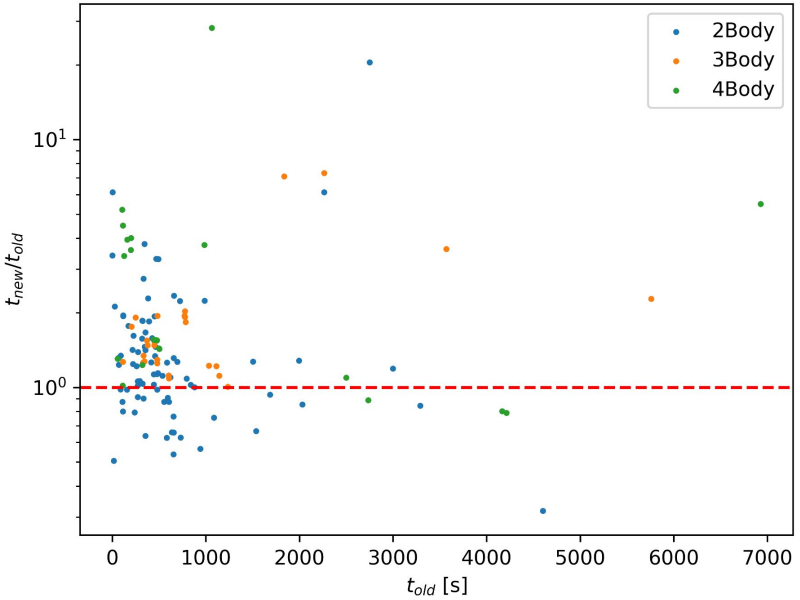
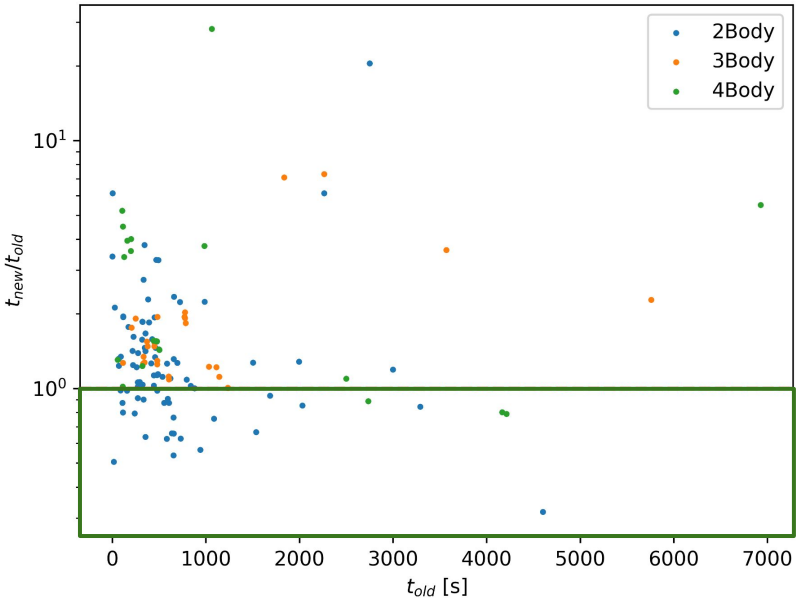


Initial performance

- Initial performance
  - 134 sets
  - ~500 combiners
  - ~1100 lines affected
- Naive combination
  - Full set always combined
- Overall most sets perform worse
- Modular framework
  - ~6% improvement on selections
  - ~2% improvement on total trigger timing
- Slower because of additional combinations
- Potential improvements:
  - Identifying optimal combination sets
  - Simplifying cuts



Conclusions & Outlook

- This work has focused on
  - Control flow optimization
  - Combiner optimization
- Work is ongoing
  - Control flow give a speed up of 16.7%
    - Thorough checks to confirm that output is the same
    - Further optimization
  - Initial results for combiner optimization shows slight improvement of only 2%
    - Optimal combination sets
    - Simplifying cuts
    - Storage gains?

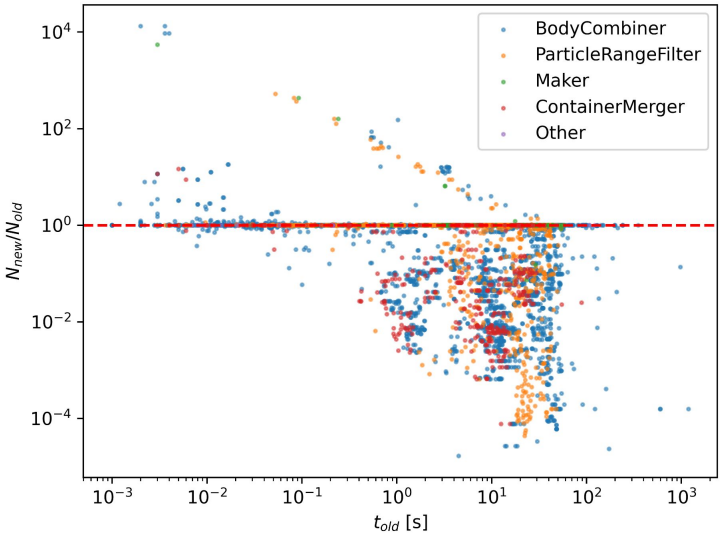
Training & Outreach

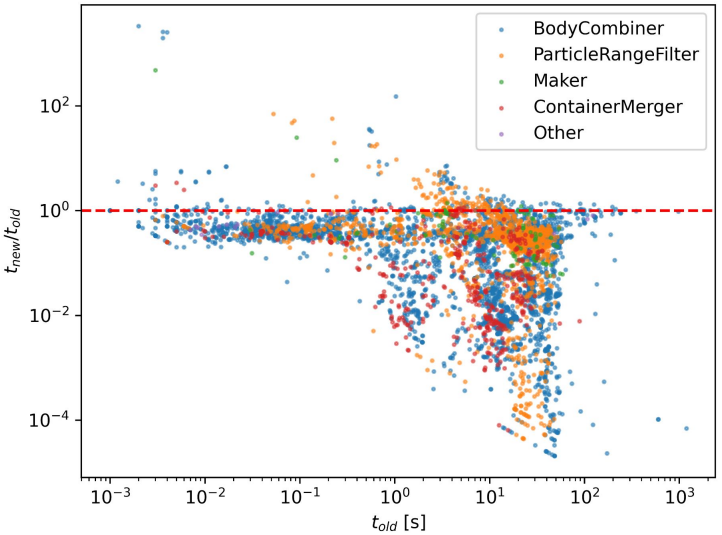
- Teachers assistant:
  - CP violation course
- BND school:
  - Physics school on various astro and particle physics subject
- Efficient Scientific Computing(ESC23) school:
  - Programming school covering various ways to design efficient computing
  - C++, GPUs, OpenMP, MPI, TBB, Floating point, Memory usage
  - Gave a lightning presentation
- NNV yearly conference
  - 15 min presentation at national dutch physics society conference
- Poster on LHCb Run 3 trigger at NWO Physics in January

Thank you for your attention! Questions?

Control flow results

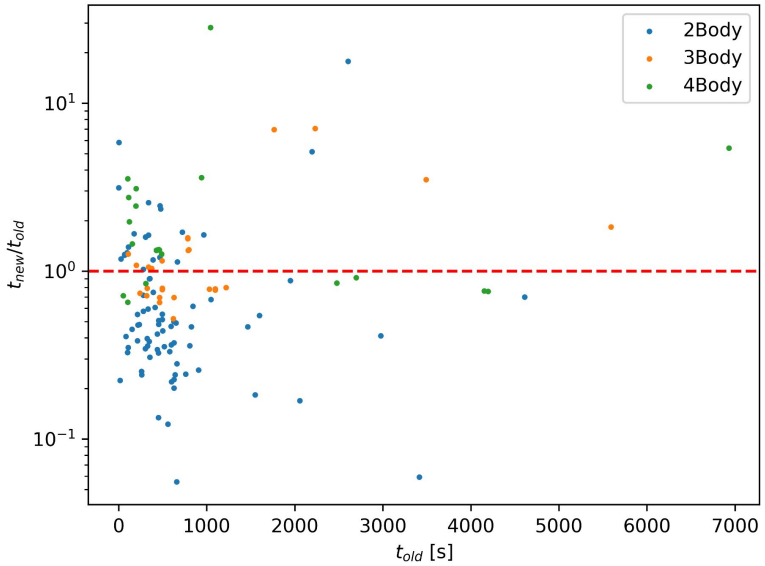
- Performance per alg
  - Event ratio
  - Timing ratio





Initial performance

- Combiner + Input Filters
  - Separation filters are very expensive
  - Ongoing work in simplifying the cuts



- Full version