Thoughts for European Strategy (Simulation) Input from ALICE

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ALICE Sim in Run3

- **ALICE has already seen its major detector upgrade for Run3**
  - New TPC at 50kHZ continuous readout
  - New ITS
  - Factors higher data rates compared to Run2

- **Run3 saw significant software rewrite: Alice-O2 project**
  - General transition from serial to parallel computing and multi-core GRID usage
  - Simulation: Multiple Geant4 workers treating sub-events (collaboration on single PbPb level to reduce memory pressure with high CPU efficiency)
  - Complete redesign of digitization to account for continuous readout and timeframe structure

- **Detector simulation workflows consume major CPU share (~60%)**
  - Next to Geant, digitization is actually a major consumer of resources

Recent and current Fast(er)sim developments

- Implemented signal-background injection (background caches) similar to LHCb
  - Simulate background minimum bias events only once
  - Combine/overlay with multiple signal events at digitization level
  - Saves factors in Geant time

- Implemented event pools/caches on the GRID
  - Some events are notoriously hard to generate → Create library of events with a specific signal
  - Reuse events (potentially phi-rotated) in several sim campaigns
  - Saves factors in event generation time

- Automatic cut tuning framework for Geant4
  - Invested in automatic mechanism to tune transport parameters of Geant4
  - Achieved ~20% speedup of full sim with similar physics output

- Implemented Delphes-like framework to generate AOD directly from generated events
  - Massively used for Run5 upgrade studies

- Fast ML sim for ZDC
  - ML Models GANs, etc.
  - Still to be pushed to production level (lacking manpower)

- Integration with GPU (Celeritas/Adept) prototypes under way

ALICE Sim in Run4 (and beyond)

- ALICE Run4 will conceptually be similar to Run3
  - Major (high-lumi) upgrade already happened in Run3
  - Some further increase in data volume, but limited by 50kHz TPC for PbPb
  - In principle continue to use (refined) software framework developed for Run3
  - Possibly invest to port additional algorithms (digitization) to GPU
  - Replace more full-sim by faster sim if appropriate

- Some challenge due to novel detector components
  - New forward hadronic calorimeter (FoCal) —> ML FastSim will be imperative
  - Upgraded ITS tracker

- Run5 may see a completely new installation called "ALICE3"
  - Possibly simplified detector (no TPC - large ITS tracker)
  - —> Likely reduced computing complexity in steps like digitization that may offset increased computing need from higher rates etc.

General important statements for simulation

- Expect that simulation, without a doubt, stays a cornerstone in HEP computing

- Expect fast simulation developments to gain even more traction/importance

- Like to benefit from GPU availability and upcoming technology evolution
    - detector sim with GPU acceleration
    - Adopt GPU for digitization treatment

- Embrace AI and other innovations
    - Fast simulation at all levels; differentiable models for rapid detector prototyping
    - However:
        - Manpower in individual collaborations may be limited or not trained
        - See strong necessity to form a cross-experiment AI developer or consultancy groups (with actual manpower) that can service multiple clients; Avoid reinventing the wheel

- Invest in expanded Physics models or common tools of Geant4
    - FLUKA physics model integration very important for ALICE
    - Improved common tooling (geometry tools,CAD,visualization - parameter tuning and optimization - ..)

- Recognize and retain computing talent
    - Further promotion and good career perspectives of computing roles pivotal for success in our field