Status of fast simulations

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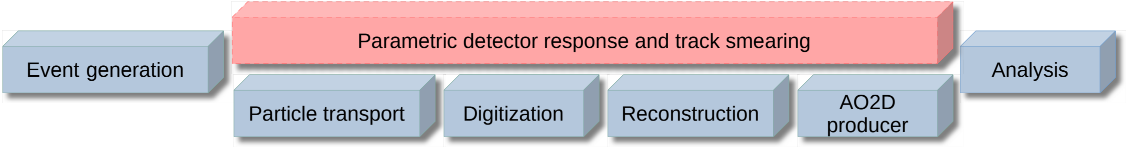
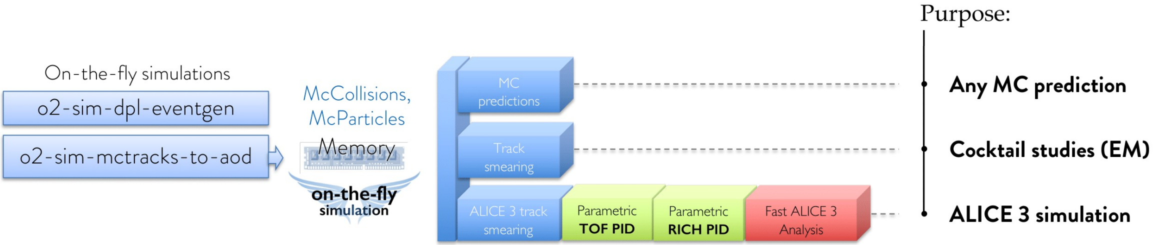
Reminder: What are "fast simulations"?

- They are simulations where one makes use of already computed detector response
- No particle transport or full reconstruction workflow increases the overall simulation speed by several orders of magnitude
- Higher simulation speed means higher storage needs
  - → Typical: 8-hour job fills 100TB disk!
- If one can avoid writing to disk one saves both I/O time and storage



On-the-fly simulations

- Simulations that are purely executed in memory, from event generation to final analysis
- One workflow in O2Physics comprised several highly configurable modules
- Existing o2sim flexibility is kept
  - → Access to built in or external generators
- o2-sim-mctracks-to-aod fills MC tables read by subsequent tracking and parametric PID tasks
  - → Just as customizable as any regular analysis task
- Status: primary event to final analysis → fully operational on Hyperloop



Track smearing with Look-up tables

Fast Analytical Tool

The FAT is what is used to smear tracks for a given input of track parameters and detector geometry.

Look-up Table

Contains several FAT solutions based on iterating over ranges in p_T, η, and multiplicity.

- For a generated track with a given set of parameters we can consider the corresponding bins in the LUT, which already contains the solution for the smearing
- For the solutions that are stored in the LUTs, it is assumed that the track is from the primary vertex
- Each LUT corresponds to ∼100MB that needs to be loaded in memory
- LUTs can also be generated from with other tools such as ACTS

On-the-fly tracker

- Load LUTs into memory: e, μ, π, K, and p
- Process generated Monte-Carlo tables
  - → Initialize tracks with perfect Monte-Carlo information

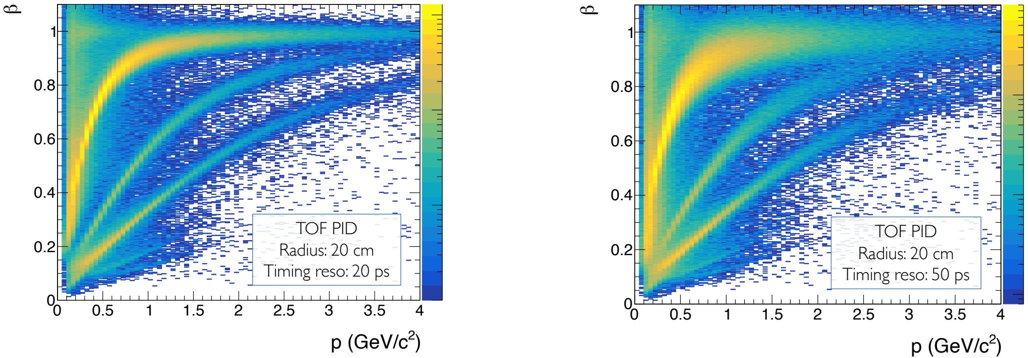
Smeared track

→ Detection efficiency
→ Momentum
→ Spatial position

- For each track we use solution in the corresponding p_{T}, η, and multiplicity bin to smear the given track
- When smearing a track the detection efficiency is also taken into account to decide whether a track was reconstructed or not
- Produce a track and collisions table, which is accessible in subsequent analysis tasks

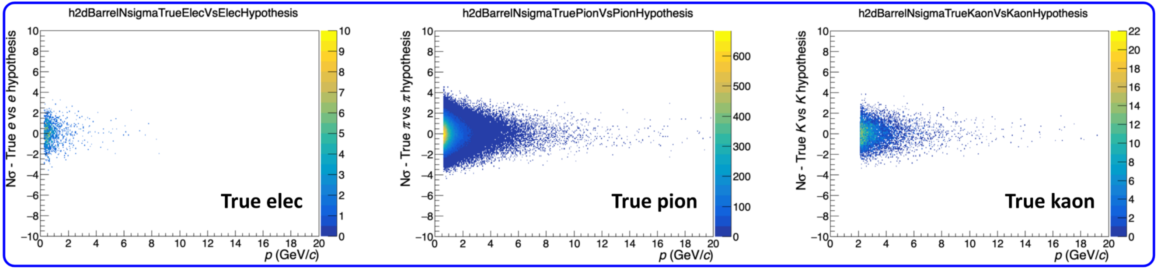
TOF parametric response

- Creates an expected time-of-flight detector signal for a set of give parameters
- E.g., radius and timing resolution
- Accesses LUTs to smear p_T and η resolution
- Direct generation of N_{sigma} for analysis



RICH parametric response

- Similarly, we also create an expected ring-imaging Cherekov signal for another set of parameters
- Again, we use LUTs to smear p_{T} and η resolution
- Direct generation of $\mathrm{N_{sigma}}$ for analysis



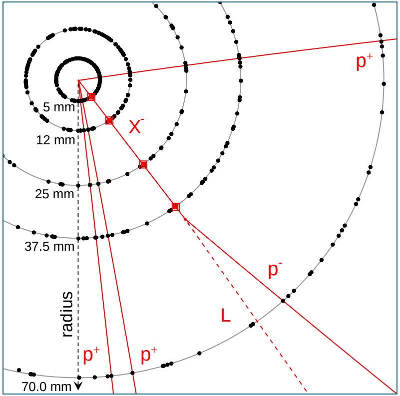
Figures from presentation by Nicola at the ALICE 3 Simulation and Performance meeting

Example: Multi-charm analysis in fast simulations

$$\Xi_{cc}^{++} \rightarrow \Xi_c^{+} + \pi^{+} \qquad (c\tau \sim 77\,\mu\text{m})$$

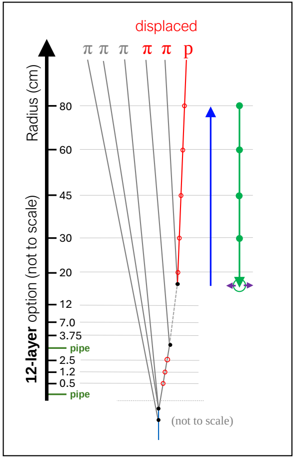
$$\Xi_c^{+} \rightarrow \Xi^{-} + 2\pi^{+} \qquad (c\tau \sim 132\,\mu\text{m})$$

6-prong, total B.R: 5% (est) x 2.9 % = **2.5x10^{-3}**



- Three primary-like pions: treated with the existing LUT-approach
- Before there was no way to deal with the weak decay in fast simulations
  - → For the letter of intent, the weak decay was treated with the full simulation
- Could we find a solution for treating weak decays in fast simulations?
  - → Requires an unprecedented, large-scale use of fast treatment of very displaced tracks

Fast simulations of secondary particles

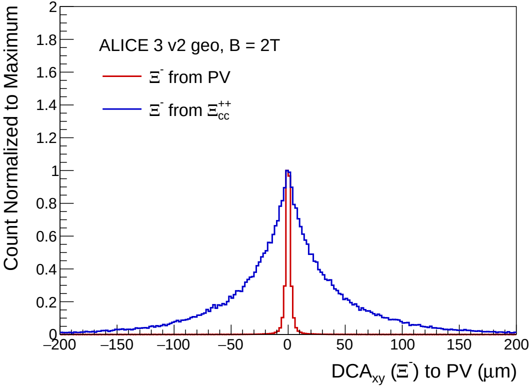


"FastTracker"

An implementation of the "FAT solver" in the OTF tracker that smears a given secondary track on a case-by-case basis.

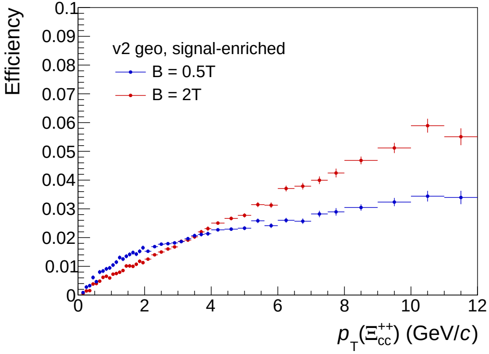
- With the "FastTracker", we are able to fully consider R_{2D} and φ_p at an acceptable CPU cost
- Current status: minimal outwards/inwards treatment
- Relevant further developments
  - Energy loss
  - Multiple scattering

Cascade reconstruction



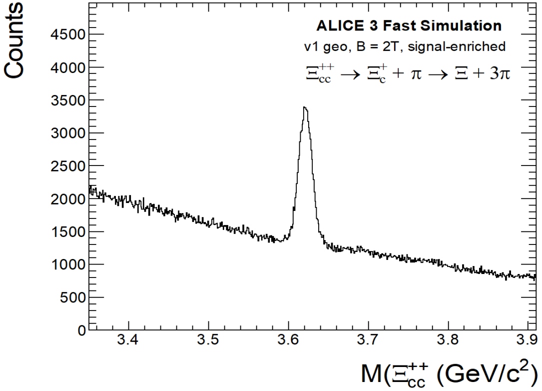
- Cascade daughters smeared using the FastTracker
- In addition to the FastTracker, strangeness tracking was also implemented in the on-the-fly tracker
  - Track reconstructed with daughter information updated with cascade hits in inner tracking layers
- Dramatically improves the ability to separate HF daughters from primary multi-strange
- Spatial resolution does not entirely match LoI results
  - → Very likely due to missing e-loss and multiple scattering

Ξ_{cc}^{++} analysis: base selections and efficiency



Selections	
Ξ_{cc}^{++} mass window	0.015 GeV/c^2
Ξ_{c}^{+} mass window	0.015 GeV/c^2
Minimum π^+ p_T (from Ξ_{cc}^{++})	0.30 GeV/c
Minimum π^+ p_T (from Ξ_{c}^{+})	0.15 GeV/c
DCA between Ξ_{cc}^{++} daughters	200 μm
DCA between Ξ_{c}^{+} daughters	200 μm
Minimum π^+ DCA$_{xy}$ to PV (from Ξ_{cc}^{++})	10 μm
Minimum π^+ DCA$_{xy}$ to PV (from Ξ_{c}^{+})	10 μm
Minimum Ξ^- DCA$_{xy}$ to PV	10 μm
Minimum tracker hits for weak decays	6 hits
η	± 1.5

Proof of concept: Ξ_{cc}^{++} with fast simulations



- "FastTracker" tool operational with "on-the-fly" monte carlo generation; no content saved to disk
- State-of-the-art tracking: strangeness tracking included in the fast tracking tool
- Enormous flexibility when testing detector layouts is guaranteed
- Next step: scale signal and background according to realistic expectations and calculate a significance and study different detector configurations

Summary

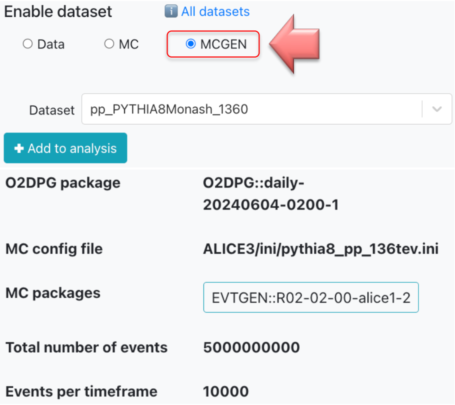
- On-the-fly simulations are available on Hyperloop for primary event analysis
- New development to the OTF tracker, which considers weak decay daughters in a case-by-case basis
  - → First version already available in the O2Physics repository: FastTracker.cxx
- Future plans
  - To be implemented: e-loss & multiple scattering
  - Performance comparison with the LUTs produced by the FAT
    - → Since the 'FastTracker' is an implementation of the FAT solver, we should reach the same results!
  - Scale invariant mass peak and background, and do significance calculation
- The finalized tool is meant to contribute to
  - → Scoping discussions
  - → Studies for the TDR

Thank you for your attention!

Backup

Backup - Tools available on Hyperloop

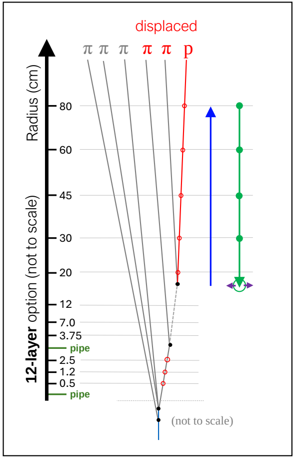
- Designated category **MCGEN**
  - No actual data is contained
  - Instead provides a link to:
    - → **EVTGEN package** version
    - → **O2DPG package** version
    - → **.ini file** in O2DPG
- Several standard MCGEN datasets exists already with auto submission enabled (2 slots per day)
- Event count for each dataset is normalized to 1 year CPU time, e.g.,
  - 5B pp/Monash tune
  - 6M PbPb/PYTHIA Angantyr



Backup - Core services on Hyperloop

- Fast simulation core service category: Hyperloop on-the-fly simulation core service wagons
- Core services include smearing utilities for ALICE 3
  - Accesses Look-up tables to smear McParticle tracks
  - Look-up tables uses various configurations such as v2-0.5T and v2-2T
  - Kept modular for efficient use
- ALICE 3 parametric TOF PID $\rightarrow$ straight to usable N_{sigma} values with multiple TOF detector possibilities
- ALICE 3 parametric RICH PID $\rightarrow$ straight to usable N_{sigma} values with multiple RICH detector possibilities
- McParticles to tracks passthrough: creates tracks from McParticles with no smearing for testing

Backup - outwards/inwards treatment



1. Outward propagation step:
   - Initialize unsmeared track at decay point
   - Propagate outwards to find points of intercept with layers
   - Stop at outermost layer reached and initialize track with perfect parameter but large covariance matrix
2. Inward propagation step:
   - Stop at each layer and update track with perfect data point and covariance matrix from expected precision
   - Final end point: original point of decay
   - Track parameters still perfect but covariance matrix represents degree of confidence in track → necessary input for smearing
3. Smearing step:
   - Diagonalize covariance matrix and change parameter vector to eigenvector basis
   - Smear parameter vector in eigenvector basis with Gaussian's with eigenvalue widths
   - Move back to standard parameter vector space

Backup - DCA comparison with LoI