Monte Carlo matching in the Belle II software

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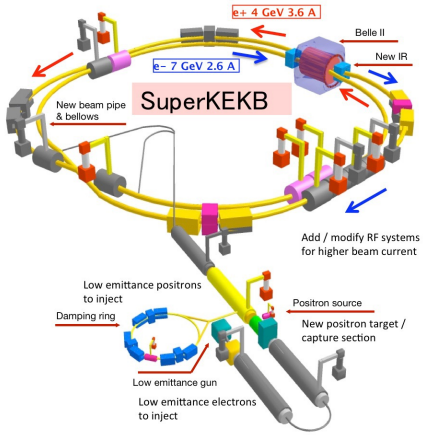
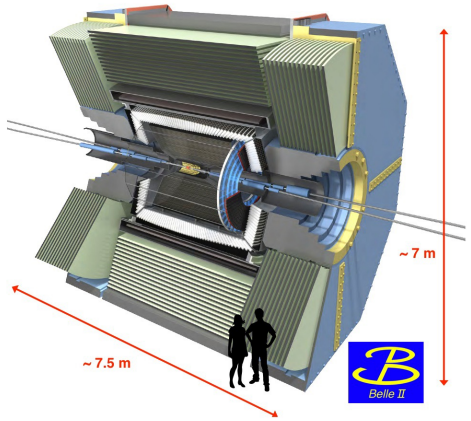
Belle II experiment

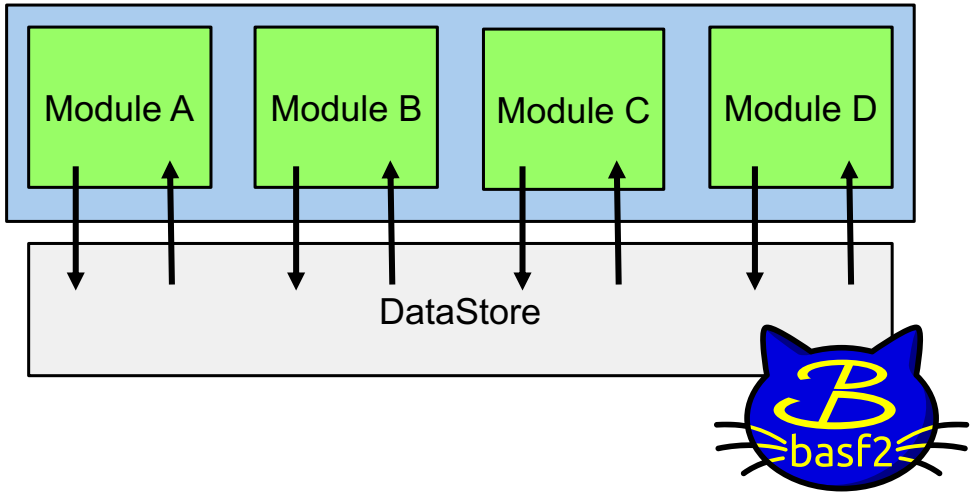
Belle II experiment is the successor to Belle.

- Both the accelerator and the detector are upgraded.



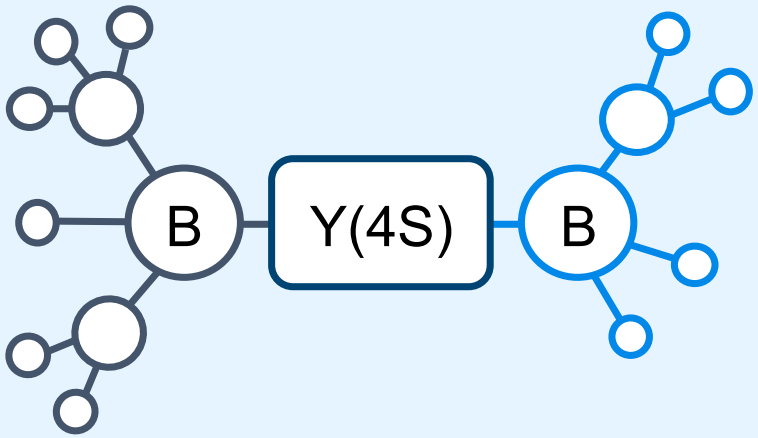


- **Belle II software has been rewritten.**
  - used for generation of Monte-Carlo events, tracking, clustering, high-level analysis, ...
  - Belle II analysis framework (basf2) is organized into *modules* which are configured in a sequence.



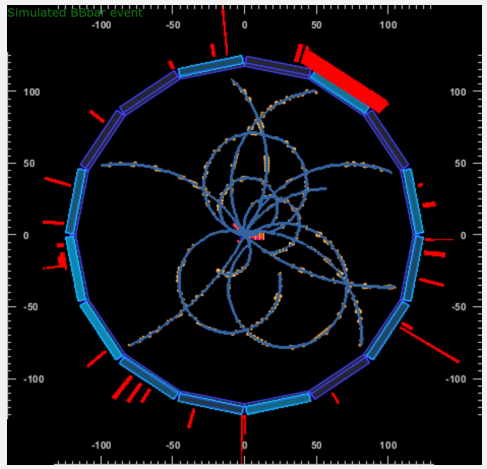
Overview of Monte Carlo simulation in basf2

Event Generation



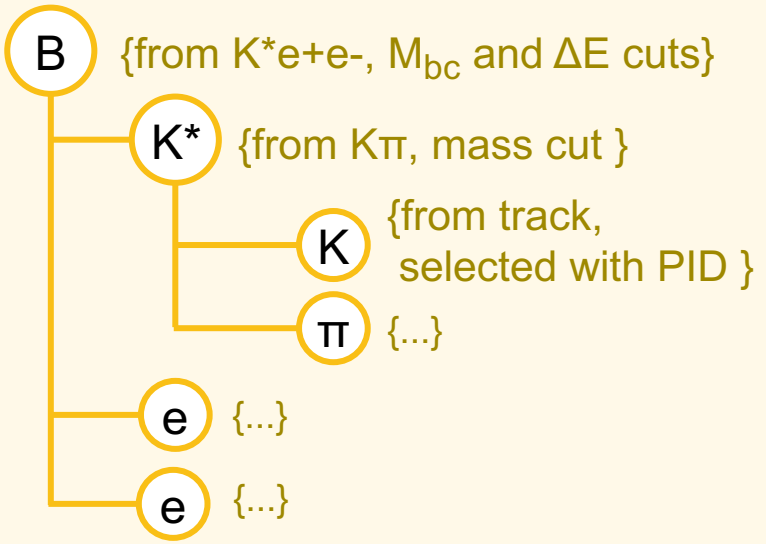
`MCParticle`

Detector Simulation



`Track, ECLcluster, PIDLikelihood, ...`

High-level analysis



`Particle`

Monte-Carlo (MC) matching

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MC-matching

- MC-matching is an important feature of Belle II software for ...
  - investigation of detector effects
  - analysis of backgrounds
  - estimation of signal efficiency

- MC-matching of *final-state particles* (track, cluster) inherits the detector information.
- For *composite particle* (such as K* and B), Belle II employs a two stage process.

☐ Find an MC-match for composite particles.

☐ Evaluate the MC-match to categorise candidates.

Algorithm of MC-matching for composite particles

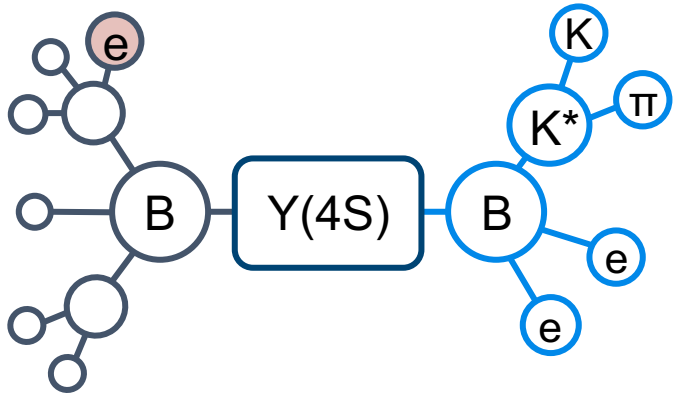
Core idea : Find ***the first common mother*** of all daughters.

Algorithm flow

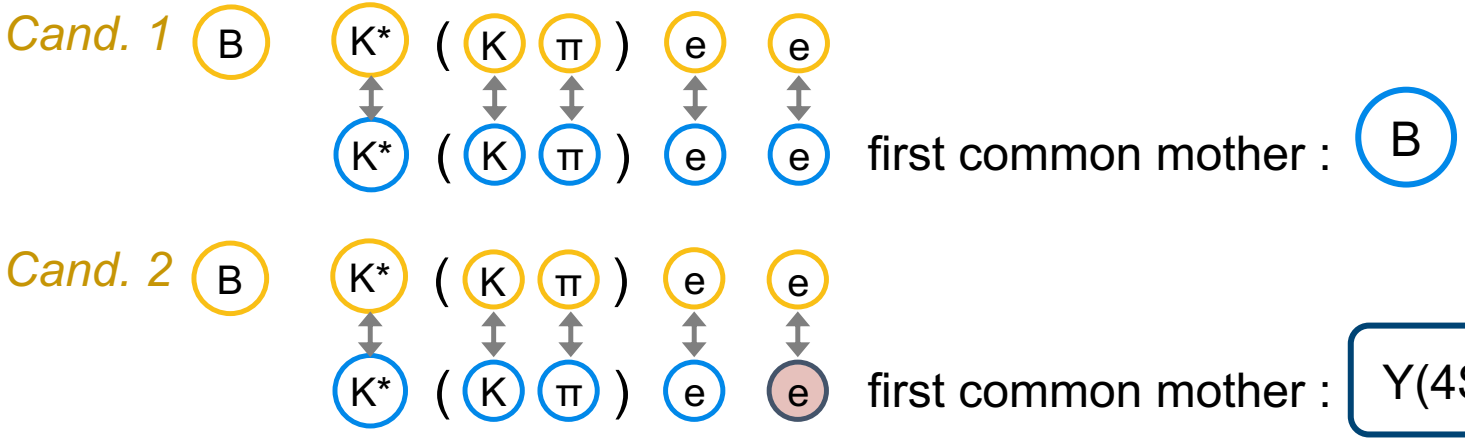
- First, check daughter's MC-matching. If a daughter is a composite particle, call the algorithm routine for the daughter recursively.
- Then, assign the most recent common ancestor (= ***first common mother***) from all MCparticles.

(e.g.) $B^0 \to K^{*0}(\to K^+\pi^-)\, e^+e^-$

Generated event : `MCParticle`



Reconstructed candidates : `Particle`



Evaluation algorithm for composite particles

Core idea : Provide ***several error flags***, so that ...

- one can identify failure cases of the reconstruction.
- one can choose to accept or not the error flags for one's own use case.

Part 1 : Process with **existing** particles.

If the MC-matching of *a reconstructed particle* is not correct, an error flag is added.

- has no daughter
  - generator-level `MisID`
  - detector-level `DecayInFlight`
- has daughters `AddedWrongParticle`

Part 2 : Process with **missing** particles.

If a daughter of the given particle is *missed to be reconstructed*, an error flag is added.

- Composite particle `MissingResonance`
- Photon `MissGamma` or `MissPHOTOS`
- Neutrino `MissNeutrino`
- Others `MissMassiveParticle`
  - Klong `MissKlong`

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User interface of MC matching

The behavior of the algorithm can be controlled with ***the decay string,***
which describes the decay chain to be reconstructed.

(e.g.) *decay string* to reconstruct $B^0 \to K^{*0} e^+ e^-$ process

- `"B0 -> K*0 e+ e-"` : the ordinary MC-matching behavior is required in this case.
- `"B0 =norad=> K*0 e+ e-"` : (*Arrow* is changed from `->` to `=norad=>`)
  No missing radiative photon is required. (Missing radiative photons are accepted by default.)

One can also configure the MC-matching intuitively with *markers* and *keywords*, for example,

- `(misID)pi+` : mis-identified on the pion is accepted.
- `?nu` : missing neutrinos are acceptable.

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Summary

- Belle II is the successor to Belle and Belle II software is completely new.
- **MC-matching** is a key feature in the MC-simulation study to understand reconstruction effects and backgrounds.
- MC-matching for *composite particles* employs a two step process.
  - Find **the first common mother** from daughters and assign as the MC-match.
  - Provide **several error flags** to categorise the reconstructed candidates.
- User interface to configure the MC-matching is provided with **the decay string**.