Belle II Analysis Models

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ROOT Users Workshop
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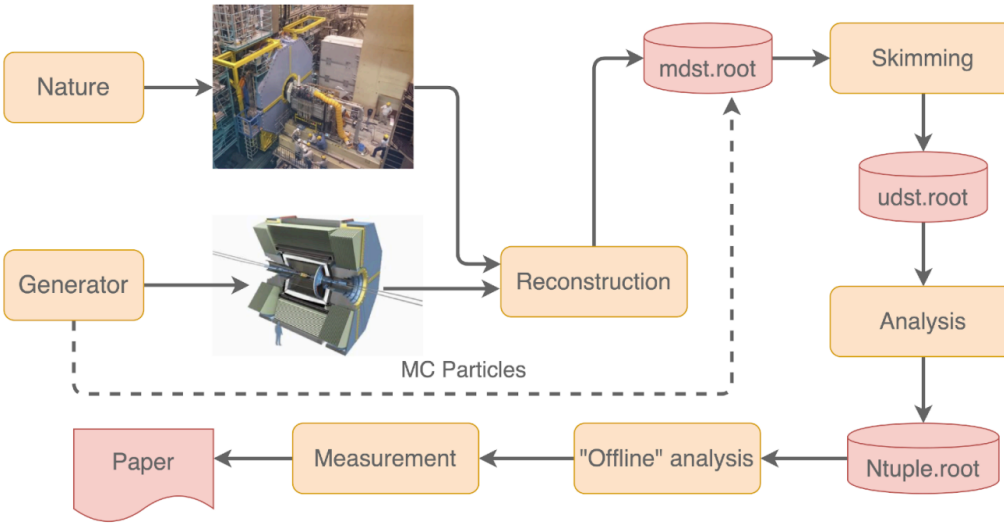
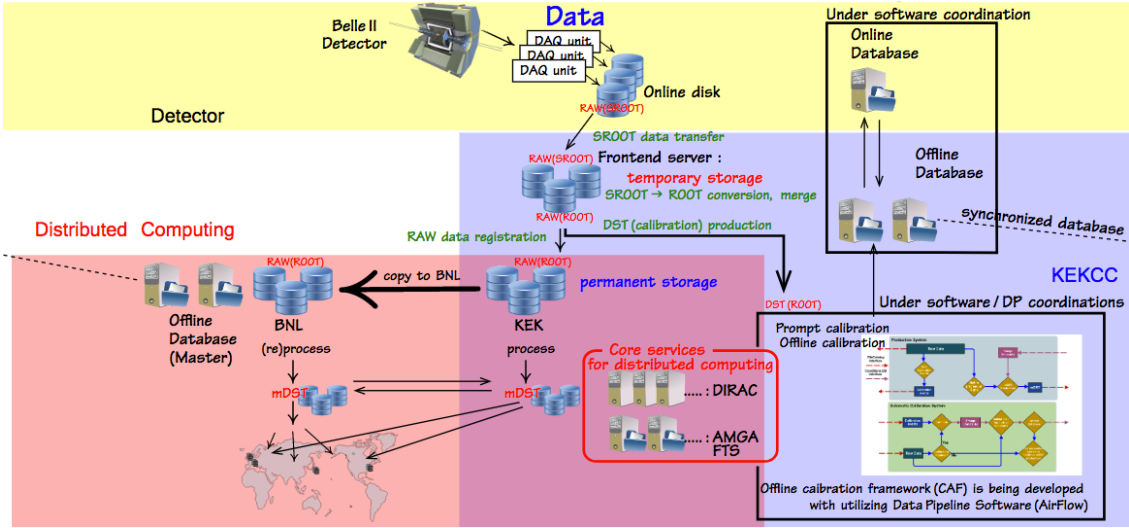
Analysis Workflow



Belle II data flow



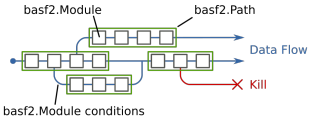
Data formats

In general, Belle II output is stored in ROOT files containing subsets of objects

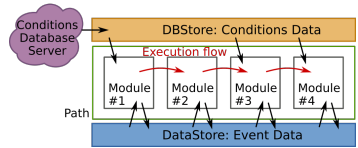
- **RAW**: raw data containing detector information.
  - ~70 kB/event
  - raw data set during 2019-2021 operation: 5 PB
- **cDST**: calibration Data Summary Table
  - ~120 kB/event
  - contains objects needed for calibration
- **mDST**: mini Data Summary Table
  - ~15 kB/event
  - strictly controlled subset of objects necessary for analysis
- **uDST**: user Data Summary Table
  - ~20 kB/event
  - mDST objects + analysis objects (ParticleLists)
  - produced from skims and intended for physics results

Belle II Analysis Software Framework (basf2)

- more than just an “analysis” framework
- performs unpacking of raw data, reconstruction (tracking, calorimeter clustering, PID), ...
- split into packages for all subdetectors as well as analysis and mva
  - can easily use our analysis tools on HLT (High Level Trigger) nodes



- C++ modules that are setup and configured via python scripts
- basf2 links against defined set of external libraries
  - ROOT, EvtGen, Pythia, Geant4, ...
  - many python packages



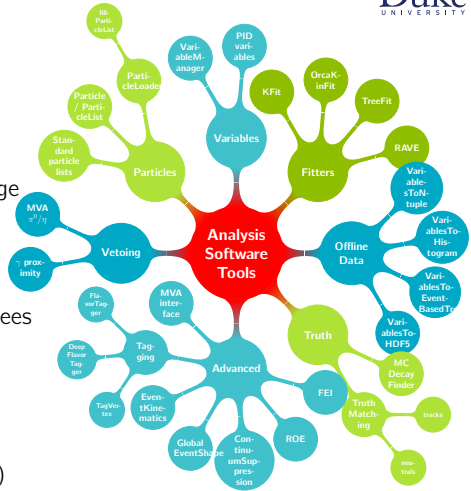
- basf2 source code and documentation publicly available at https://github.com/belle2/basf2 and https://software.belle2.org

Software releases of basf2

- major releases once a year with very thorough validation containing all software changes that are merged to the main branch (after approval of librarian)
- one or two minor releases per major releases with limited amount of new features, usually for specific purpose
- patch releases mostly for bug fixes, especially for data-taking and calibration during data-taking synchronized with maintenance days
- light releases
  - for introduction of new data analysis features
  - contain only framework, mdst, mva, analysis, skim, geometry, online_book, and b2bii packages
  - no unpacking or digitization $\Rightarrow$ only mdst and udst can be processed
  - new version about every two months

Belle II analysis package

- load data
- create particles from mdst dataobjects
- combine particles using decay strings
- apply selection cuts implemented with domain-specific language
- perform high-level analysis operations
  - vertex fits
  - (flavor) tagging
- store variables in ntuples mostly as candidate-based ROOT trees



- analysis package common for all physics working groups (WG)
  - encourage WG-specific code to be pushed to basf2
  - option to (easily) run specialized modules/variables on grid
- B2BII converts Belle data format into Belle II data format

Belle II analysis package

```python
import basf2
import modularAnalysis as ma
import stdV0s
import vertex
import variables.collections as vc

# create path
main = basf2.create_path()

# load input data
ma.inputMdst('inputfile.mdst.root', path=main)

# create ParticleLists
ma.fillParticleList('mu+:good', 'PIDmu > 0.9', path=main)
stdV0s.stdKshorts(fitter='TreeFit', path=main)

# combine particles
ma.reconstructDecay('J/psi:wide -> mu+:good mu-:good', 'abs(dM) < 0.01', path=main)
ma.reconstructDecay('B0:final -> J/psi:wide K_S0:merged', 'Mbc > 5.24', path=main)

# perform vertex fit
vertex.treeFit('B0:final', conf_level=0, massConstraint=['J/psi', 'K_S0'], path=main)

# store variables in output ntuple
ma.variablesToNtuple('B0:final', variables=vc.kinematics, filename='outputfile.root', treename='tree', path=main)

# process events
basf2.process(main)
```

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Offline analysis

- performed at kekcc (Japan), at National Analysis Computing Facilities (at DESY or INFN), or on local machines
- no coherent Belle II offline analysis framework
  - analysts are mostly on their own on how to get the physics results out of the data
  - surveys showed that people use full range of options: C++, python, ROOT macros, Jupyter notebooks, ...
- MVA method interfaces provided within basf2 (FastBDT, TMVA, ...)
- fitting tools task force
- systematics framework