The Software Library of the Coming Belle II Experiment and its Simulation Package

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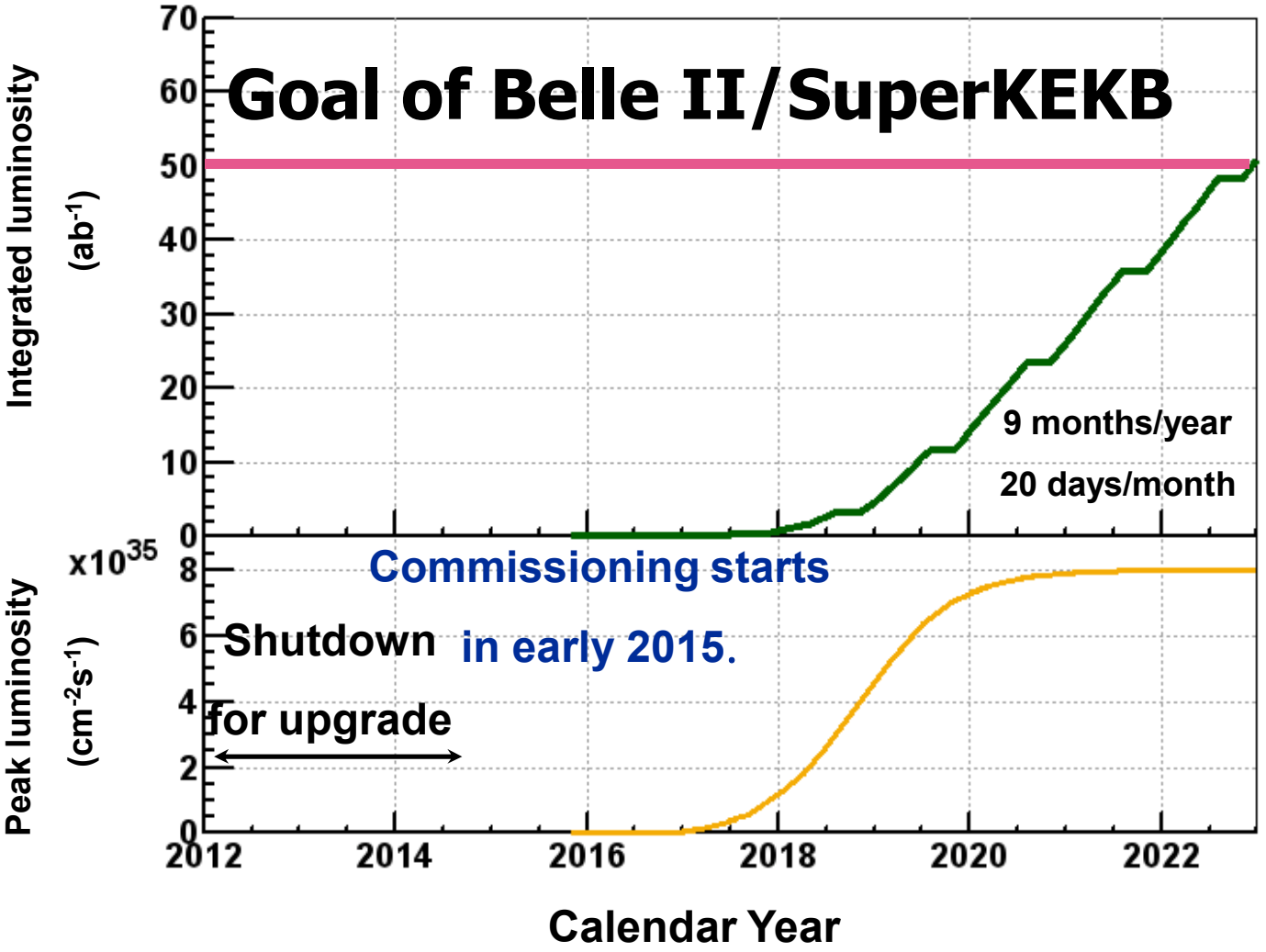
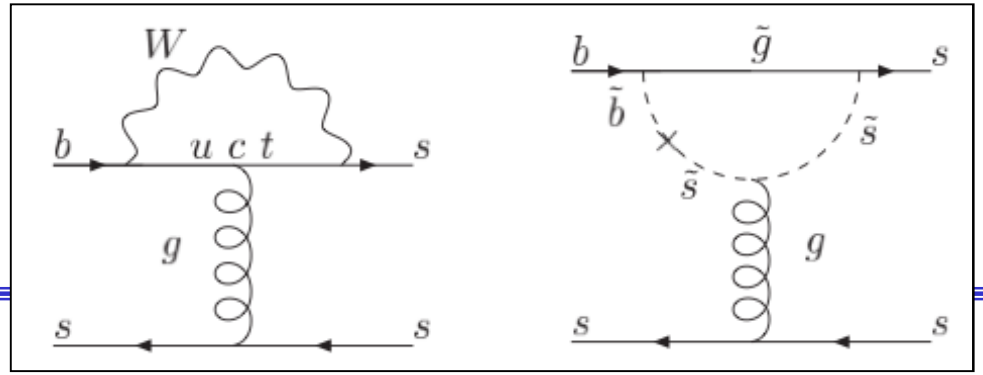
Belle II

SuperKEKB Luminosity Projection



Physics at a Super B Factory

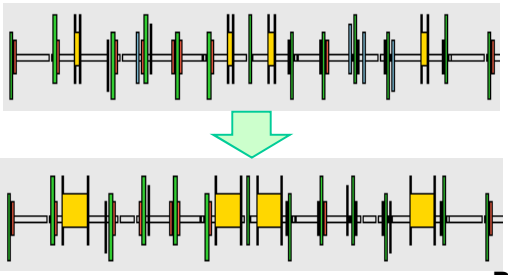
- A B meson is a long lived particle with many interesting decay modes. Easy to identify and study the decay process.
- Precision test of CKM unitarity matrix
- There is a good chance to see new phenomena:
  - CP Violation from the new physics .
  - Lepton flavor violations in τ decays.
  - Search for the charged Higgs boson in B→$\tau\nu$, D(*)$\tau\nu$ decays.
  - New particles affecting the flavor changing neutral current.
  - More topics: CP Violation in charm mesons, new hadrons, …



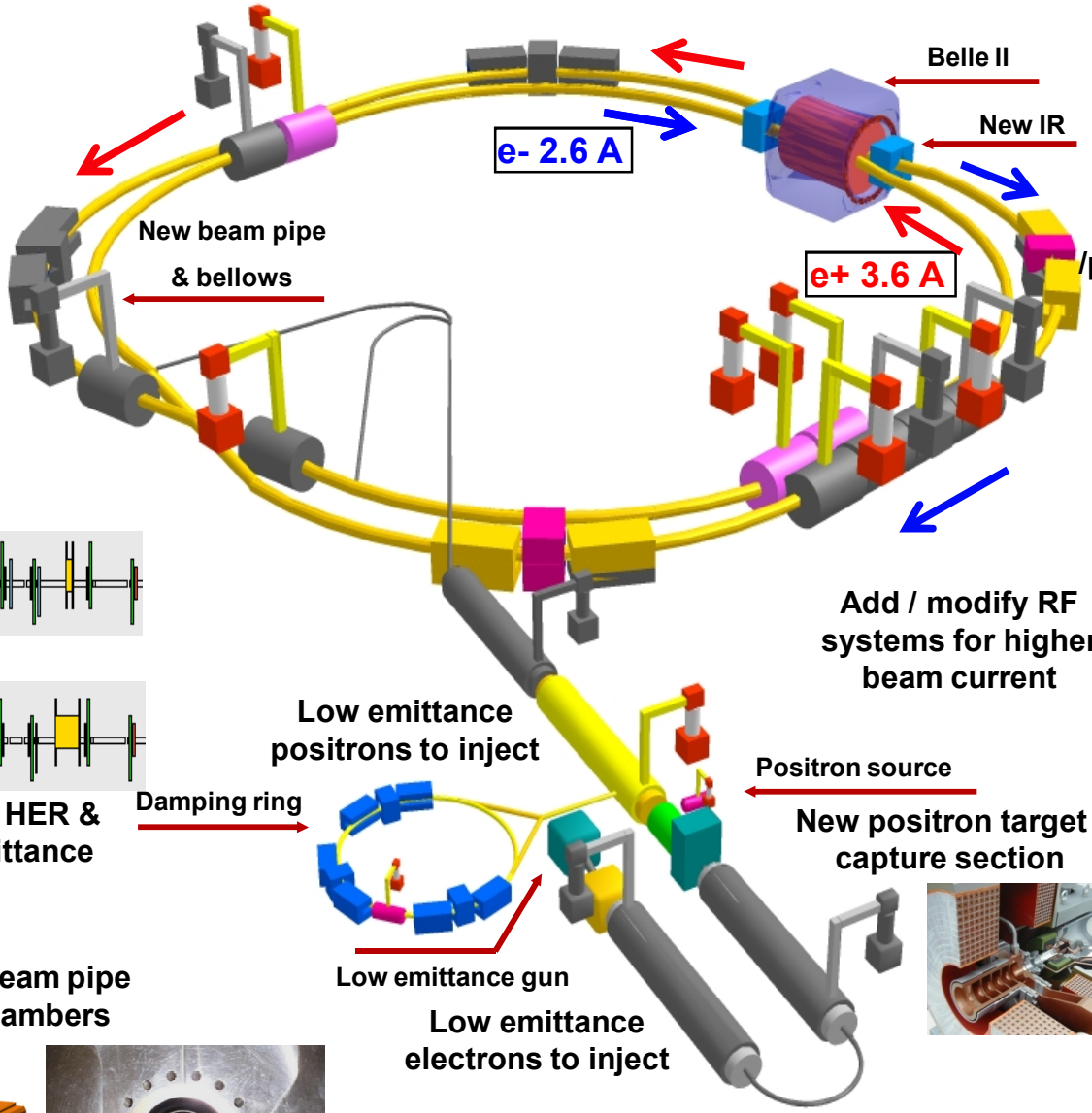
Upgrade Process to SuperKEKB

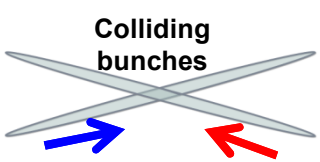
Super KEKB uest for BSM

Replace short dipoles with longer ones (LER)

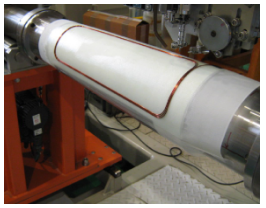


Redesign the lattices of HER & LER to squeeze the emittance



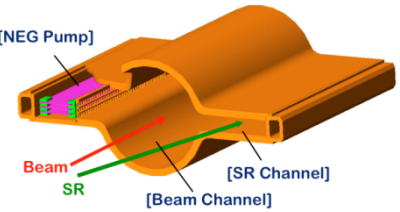


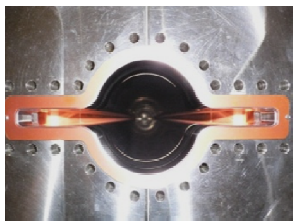
New superconducting /permanent final focusing quads near the IP



Add / modify RF systems for higher beam current

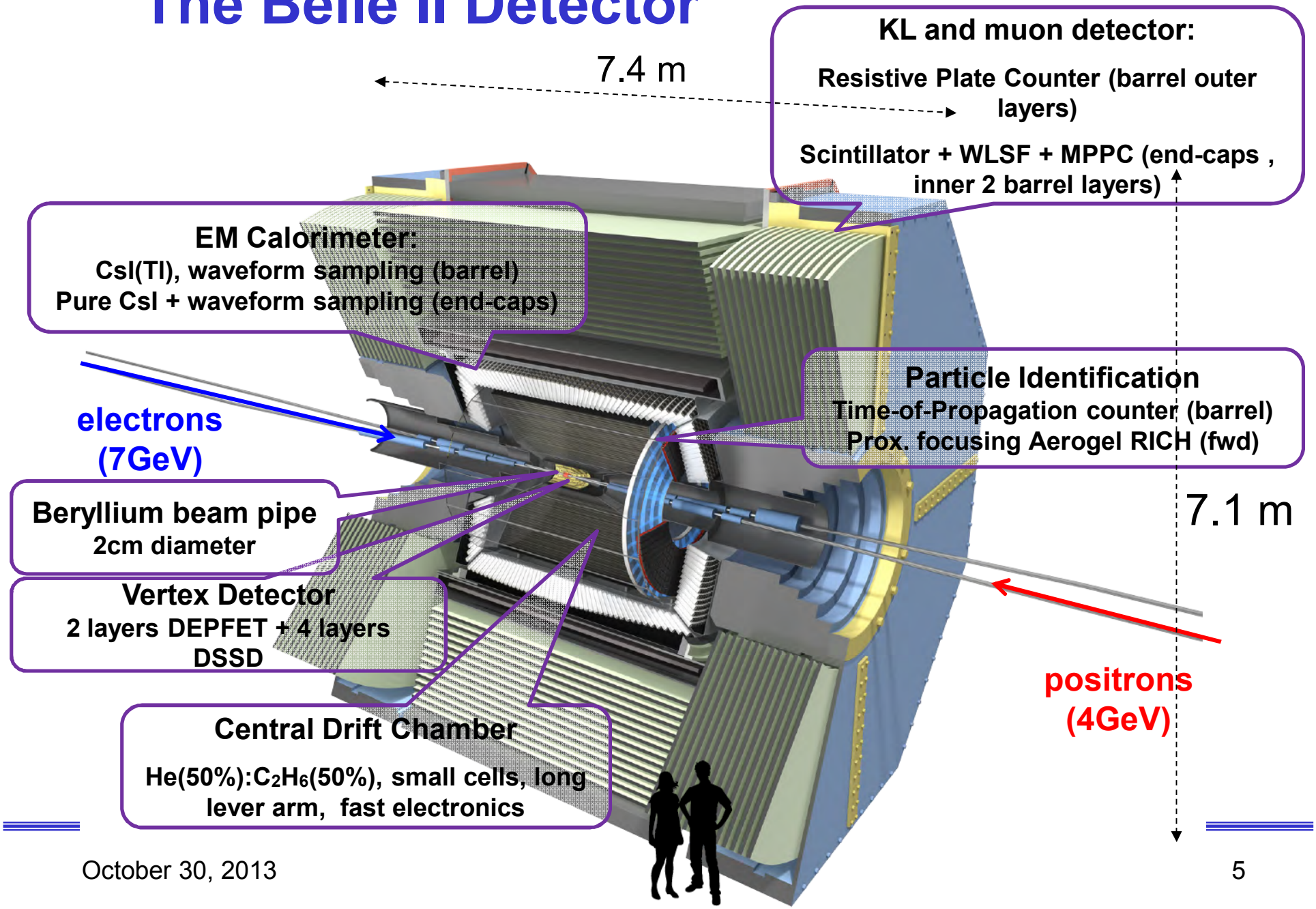
TiN-coated beam pipe with antechambers





To get x40 higher luminosity

The Belle II Detector



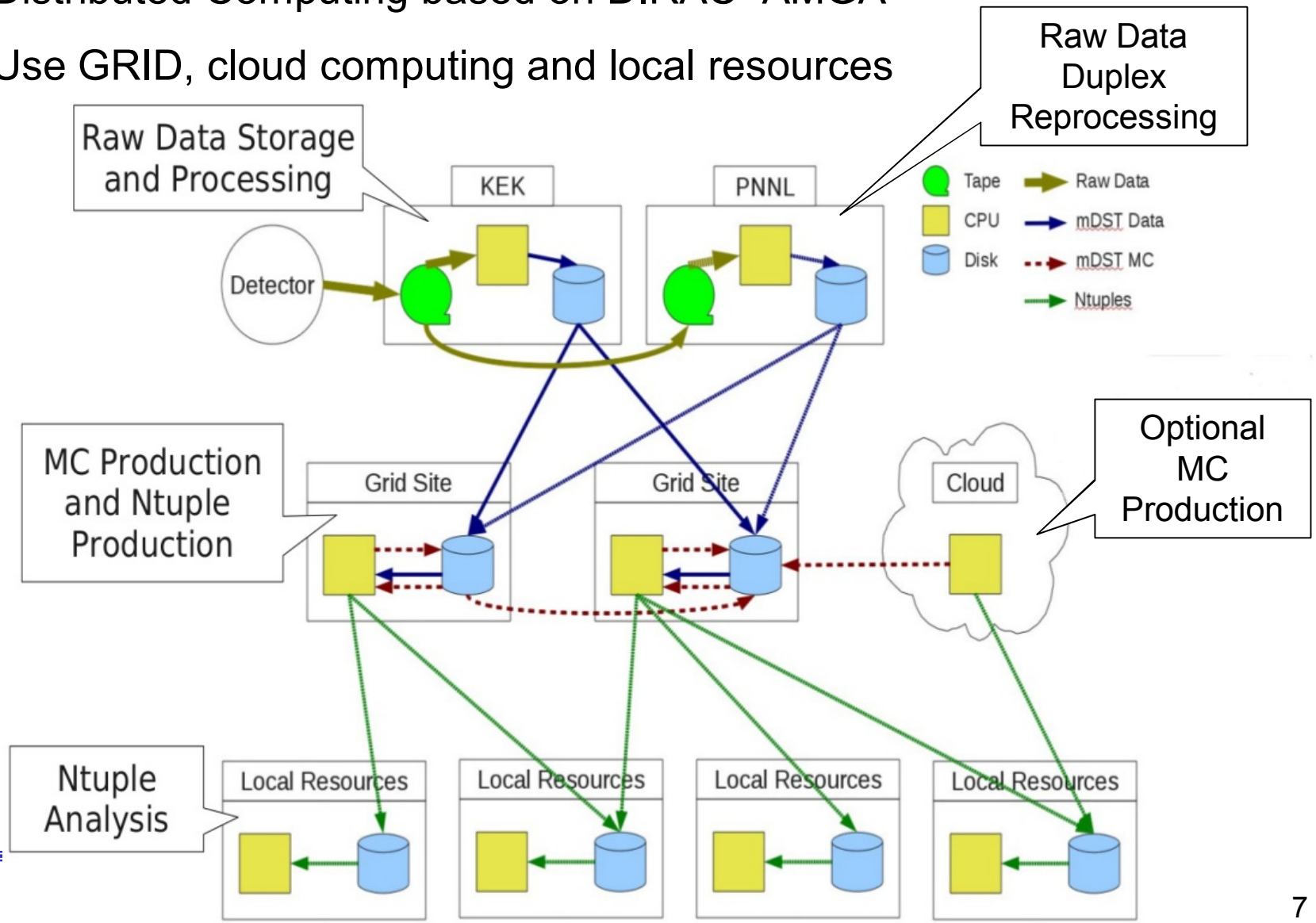
DAQ - Event Rate

Experiment	Event Size [kB]	Rate [Hz]	Rate [MB/s]
High rate scenario for Belle II DAQ			
Belle II	300	6,000	1,800
LCG TDR (2005)*			
ALICE (HI)	12,500	100	1,250
ALICE (pp)	1,000	100	100
ATLAS	1,600	200	320
CMS	1,500	150	225
LHCb	25	2,000	50

* The LHC experiments are running at a factor of two or higher event rates

Distributed Computing System

- Distributed Computing based on DIRAC+AMGA
- Use GRID, cloud computing and local resources



The Belle II Software System

- A “framework” system with dynamic module loading, parallel processing, Python steering, and ROOT I/O
- Full detector simulation with Geant4
- Code management systems at KEK: The Subversion software
- All common linux operating systems supported: SL, Fedora, Ubuntu, etc
- C++ 11 and gcc 4.7
- Formatting tool: astyle
- Building: scons and buildbot system
- Documentation: Doxygen, Twiki
- Issue tracking: Redmine

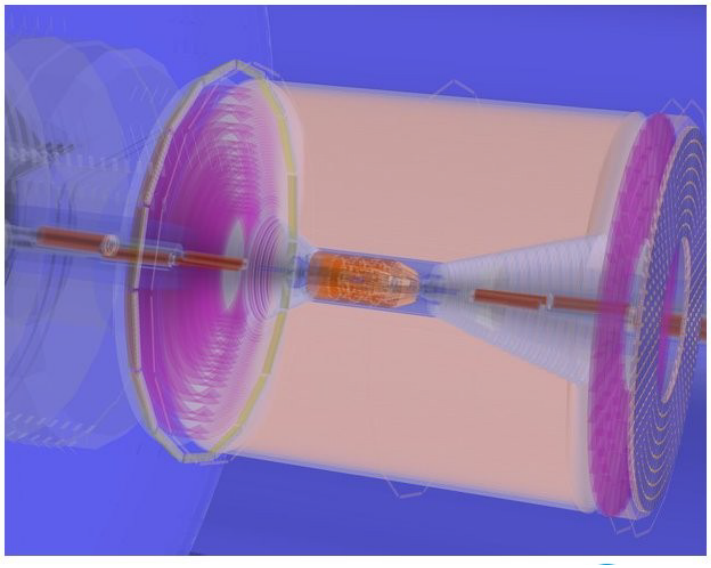
The Upgrade of the Software from Belle

- BASF2 (**B**elle **A**nalysi**S** **F**ramework 2)
  Basic ideas from the Belle software system + Constructed from scratch.

- Old system: C++. Panther tables to store data.
- New system: C++ based. Object oriented.

- Imported useful concepts from other experiments:
  ILC, LHCb, CDF, and Alice

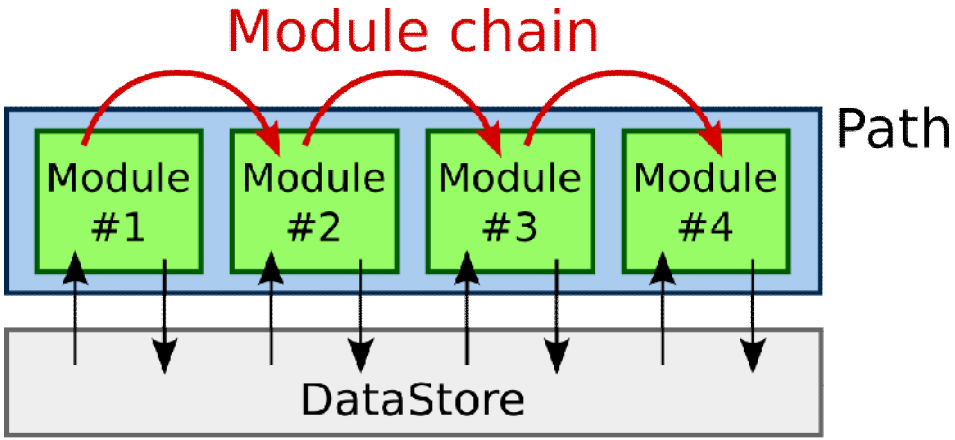
- Third-party software libraries:
  ROOT, boost, CLHEP,
  and many others.



- Software developers are from all around the world.

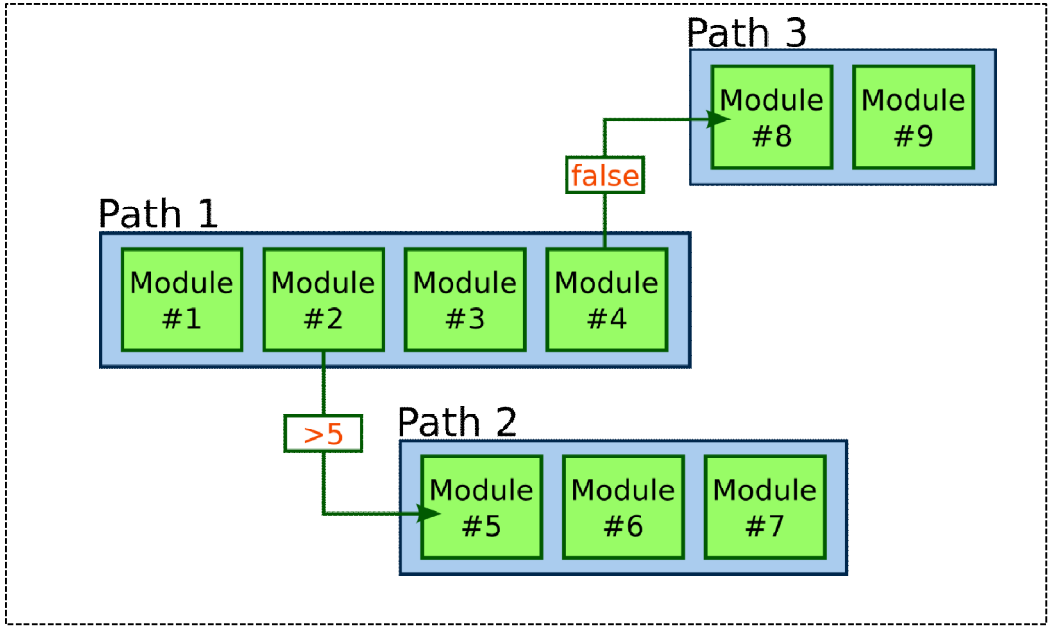
Panther: Belle's own data persistency tool, written in C and C++

The Basic Structure of BASF2

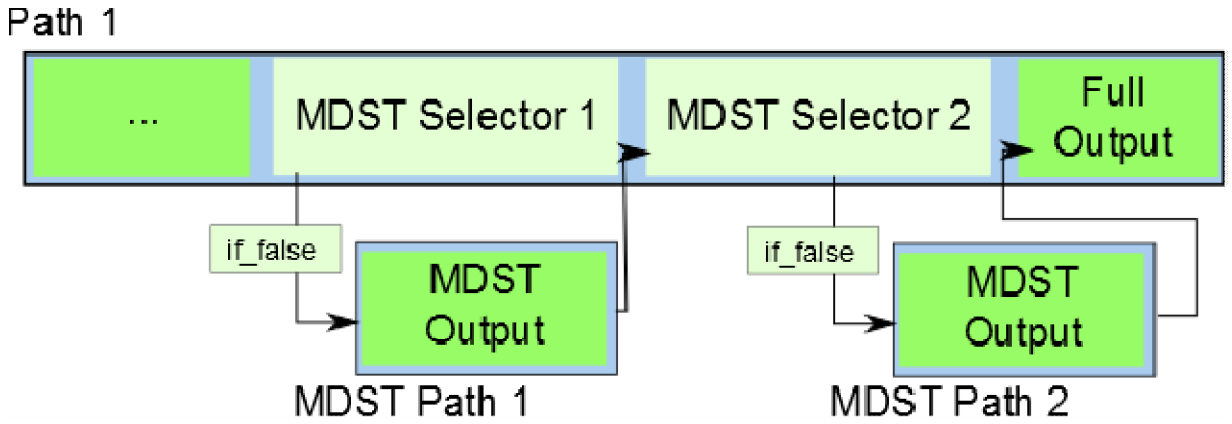


- **Module**: The basic processing unit
  - Examples: As simple as reading data from a file
    to complex ones like simulation or tracking
  - All the works are done in modules.
  - Selection and arrangement of the modules are done by a user.
- A typical event processing = a linear chain of modules on a **path**
- **Datastore**: A common storage for data

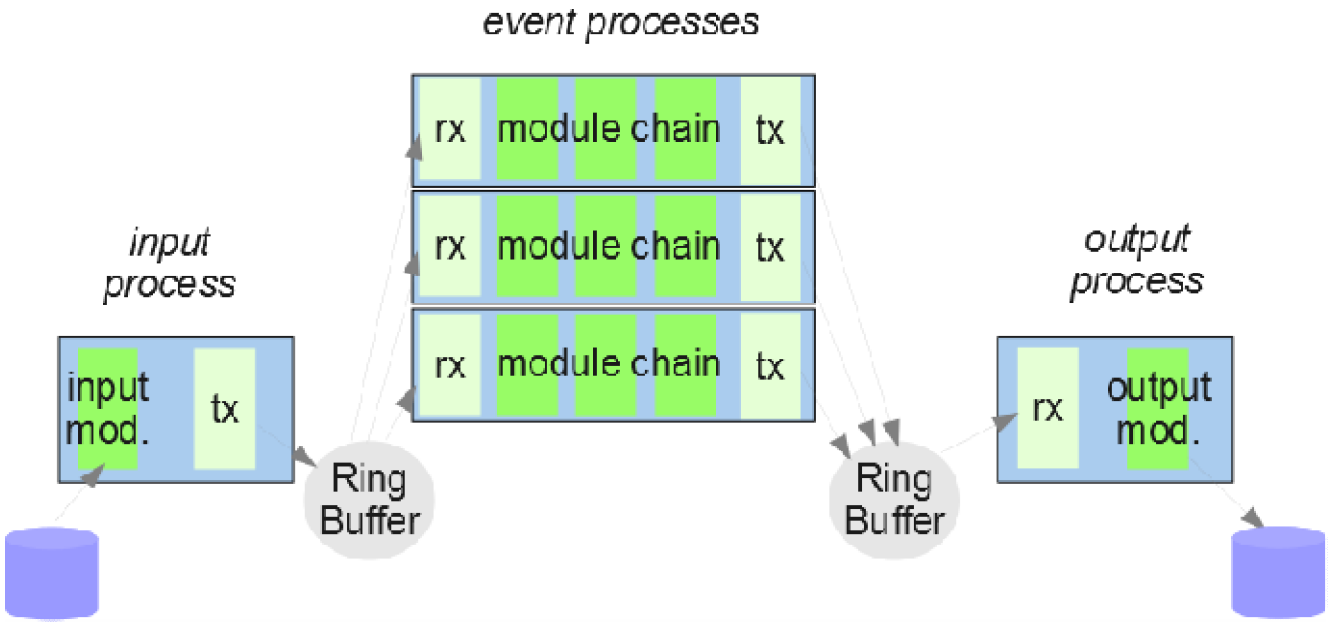
Multiple Processing Paths Available



- Multiple paths are allowed.
- The paths can be created and merged by **conditions**.
- Useful for skimming data.

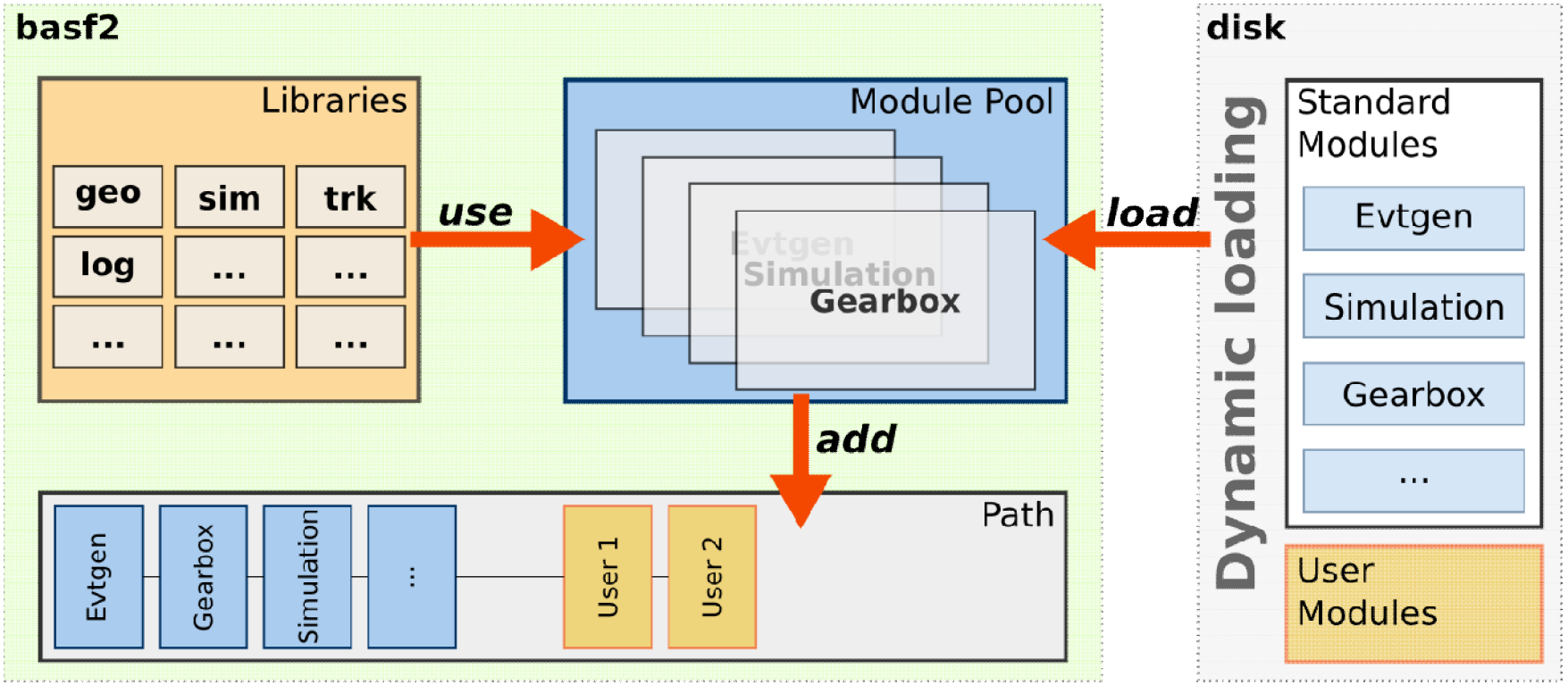


Parallel Processing



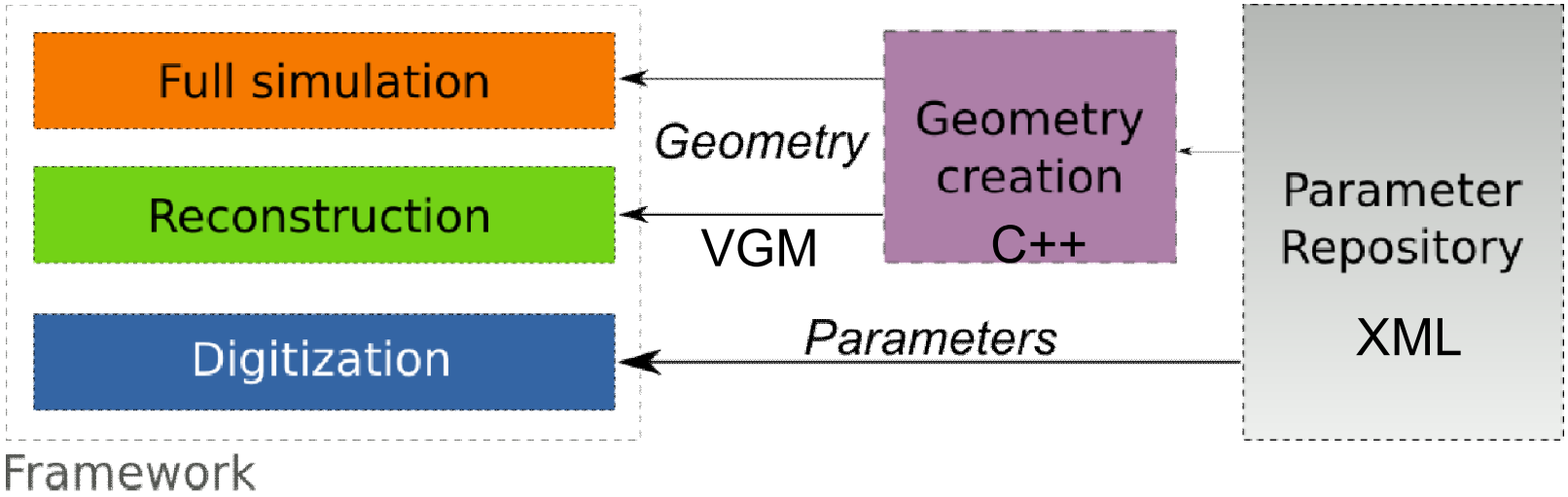
- Switching between normal and parallel processing is to be transparent to users.
- Event-by-event parallel processing.
- Linux processes forked after initialization.
- Partial parallel processing:
  - Input and output processes are run in a single path.
  - Only the modules with parallel processing property are run in a parallel path. Example: MC simulation

Libraries vs Modules



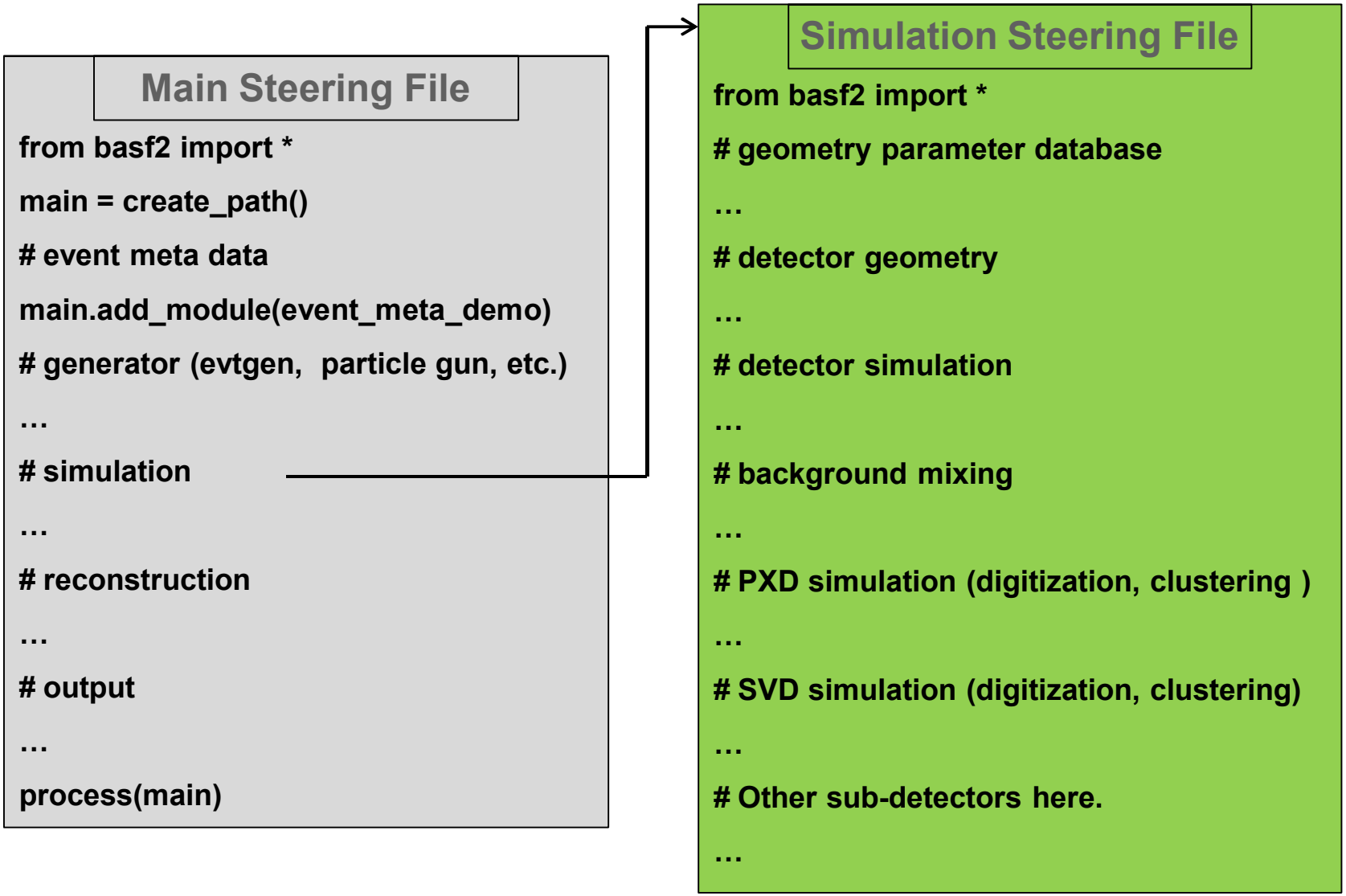
- **Libraries:** Separated from modules to increase reusability.
  - Methods and algorithms are encapsulated in libraries.
  - A library (i.e, algorithm) can be used/shared by several modules.

Geometry Handling System



- All the geometry parameter values are stored in the central repository.
- The actual geometry for simulation is created from the repository parameters via C++ algorithms.
- For reconstruction, it is converted to ROOT **TGeo** via VGM library.
- Parameter values are directly available to users. Easy maintenance and quick updates possible. Increased efficiency due to C++.

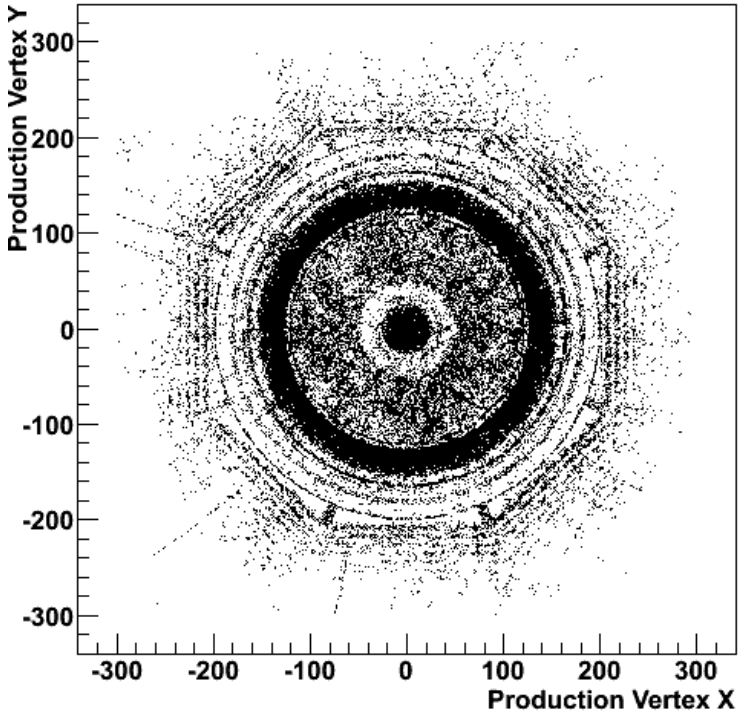
Scheme of Detector Simulation



Simulation Example:

"The Secondary Particles Created by Geant4"

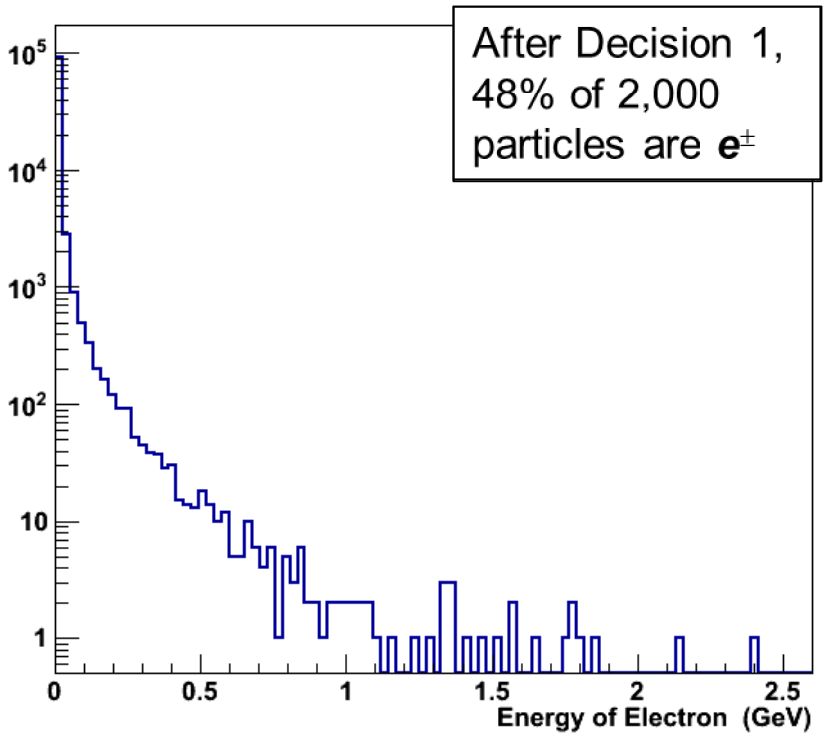
- Most of the particles simulated by Geant4 are secondary particles.
  - For example, an $\psi(4s)$ into generic B Bbar decay in the inner detectors of Belle 2 (PXD, SVD, CDC, TOP, ARICH) creates 34,000 particles during Geant4 simulation.



82%	Optical photons from Cerenkov or scintillator detectors
18%	$e^{\pm}$
0.32%	photons
0.20%	Others including primary particles

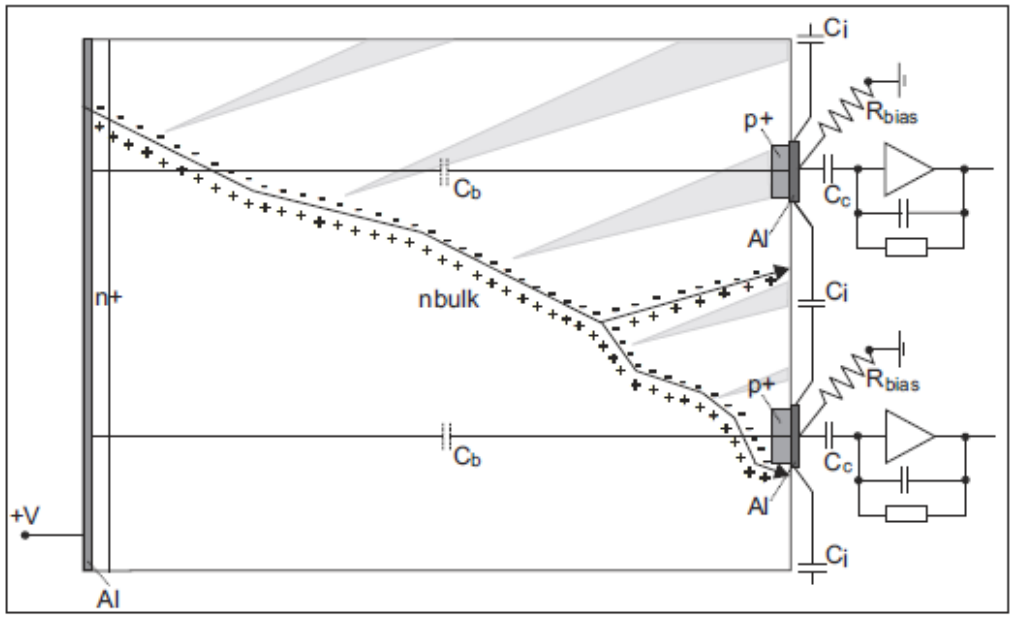
Note: Optical photons and particles < 1 MeV kinetic energy are not included in the plot. They are simply too many.

- Decision 1: In the output file, optical photons and secondary particles with kinematic energy less than 1 MeV are not stored.
- At this stage, an $\psi(4s)$ decay in the full Belle II geometry creates 2,000 particles during Geant4 simulation. The output MDST file size is still too large.
- Decision 2: Only the necessary secondary particles are kept in the output file such as
  - Decays-in-flight
  - Secondary particles leaving hits in the sensitive detector area.
  - This achieves 90% reduction for the MDST file size, which is acceptable.



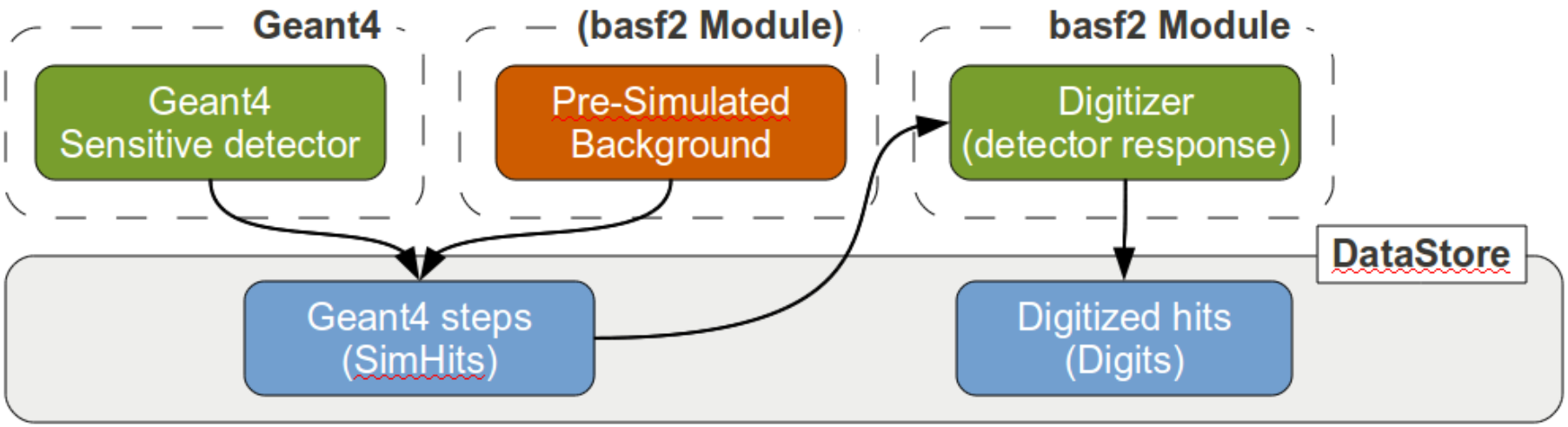
Digitization Software

- Detailed information on the detector material and electronics is needed: Sub-detector experts write the digitization code.
- Coded as modules rather than complete integration into Geant4: Different versions of sub-detector digitization would be available.



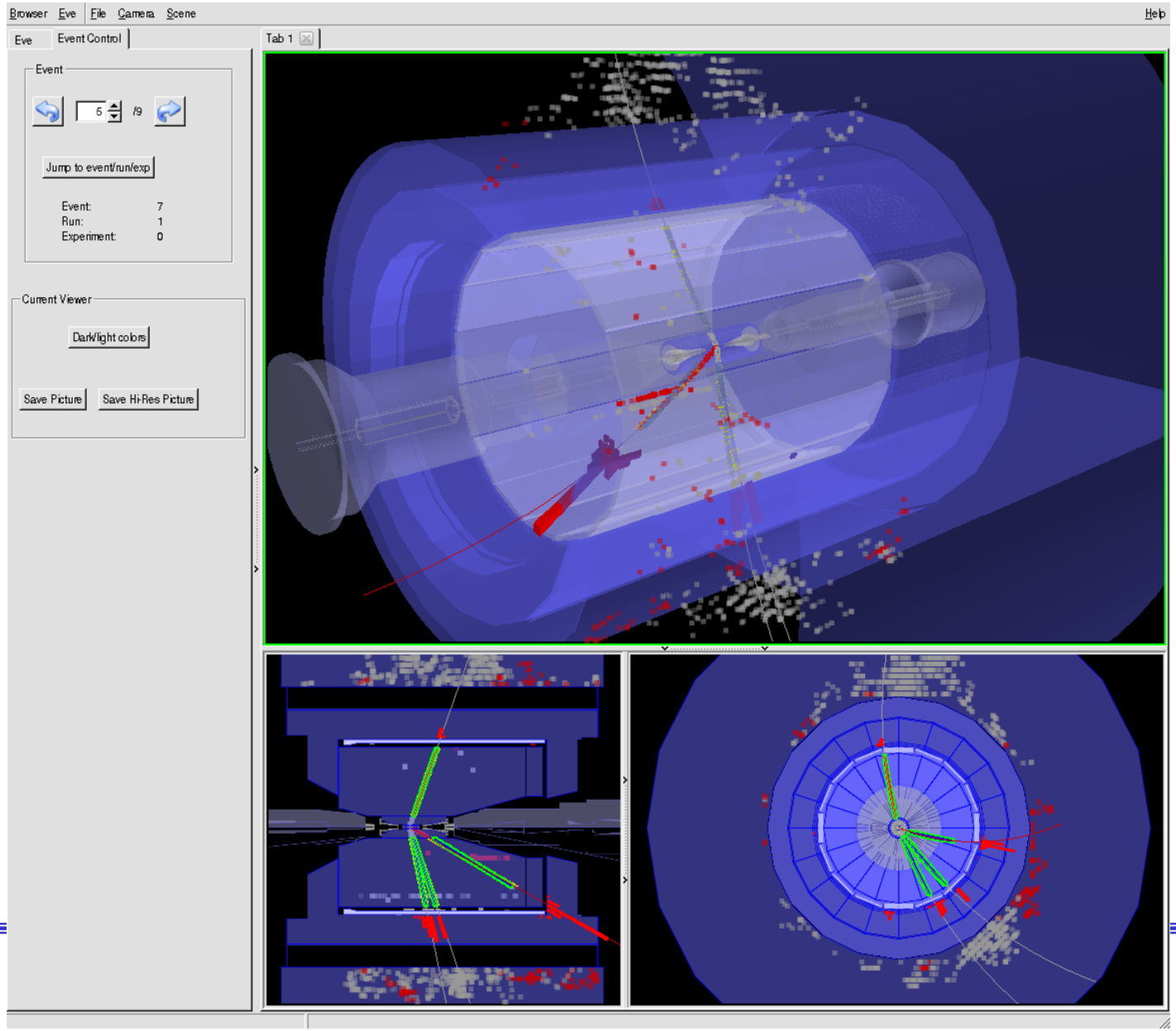
Digitization in the silicon vertex detectors.

Background Overlay



- Pre-simulated Geant4 background hits are added as SimHits (Geant4 steps) to the already existing SimHits from the signal event.
- The background events could be even beam background (Touscheck).
- Then both contributions are digitized at the same time.
- Pros: Closer to reality.
- Cons: Can’t be used for measured background data.

Event Display



Basf2 + ROOT with OpenGL support

Belle II: A Truly Global Collaboration

Chonnam N. Univ.
Gyeongsang N. Univ.
Hanyang Univ.
KISTI
Korea Univ.
Kyungpook N. Univ.
Seoul N. Univ.
Soongsil Univ.
Yonsei Univ.

- Over 500 scientists. More from Canada and Italy recently.
- Active development in software: Half a billion events were recently simulated and reconstructed at an MC campaign **without any basf2 crash.**
- Many thanks for the colleagues who provided valuable ideas, data and plots for this poster.

Super KEKB

Belle II