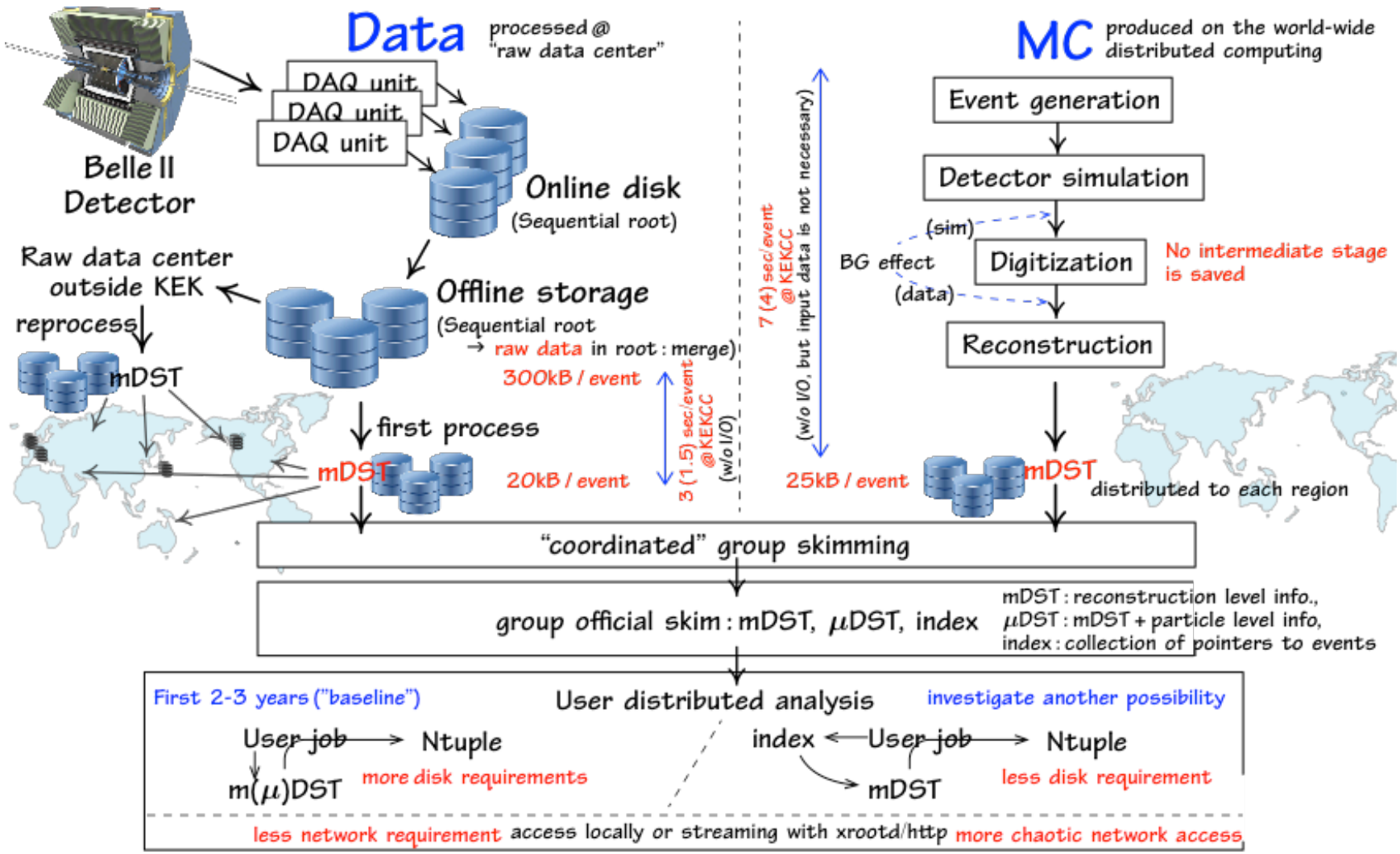
Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Overview and Highlights of the Belle II Computing and Software

MALACHI SCHRAM
PACIFIC NORTHWEST NATIONAL LABORATORY
On Behalf of Belle II collaboration

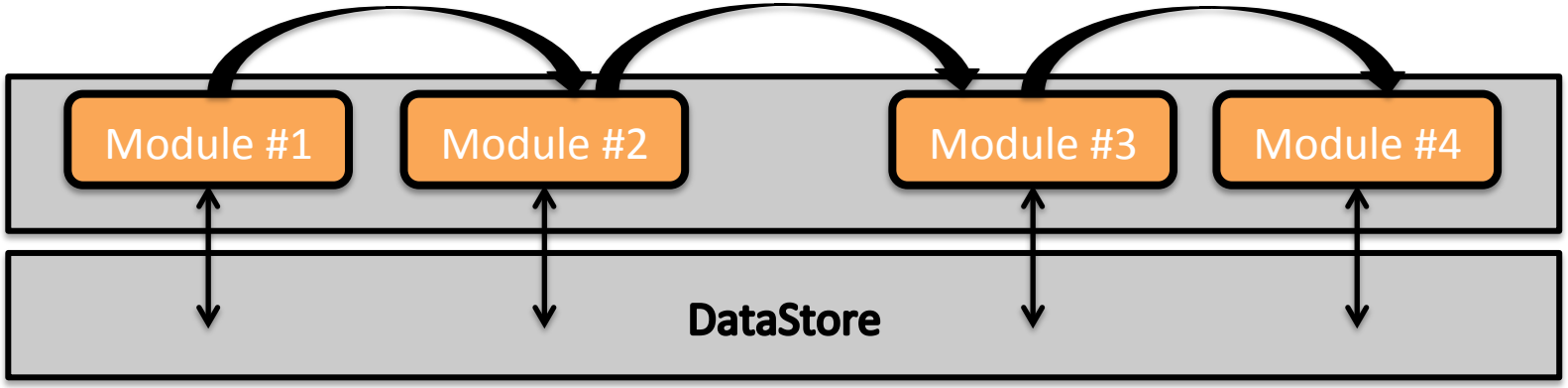
Computing and Software Workflow



Belle II Analysis Software Framework (BASF2)

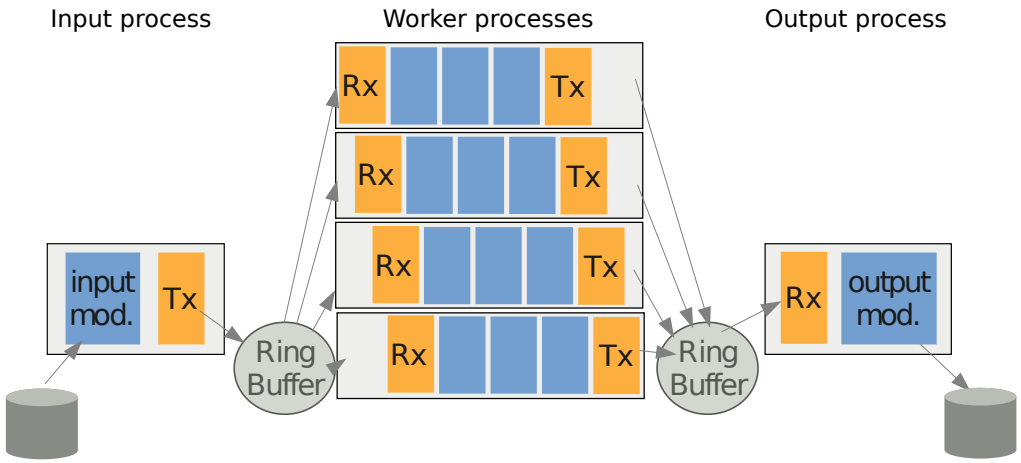
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Data Object:
  - C++ class that encapsulates the variables of a specific object
  - Various types: StoreObject, StoreArray, and Relational Objects
- Data Store:
  - Implementation in the Belle II framework to store/retrieve (share) data objects
  - Data objects can be stored per event and/or per job
- Module:
  - Algorithm that performs operations on data object

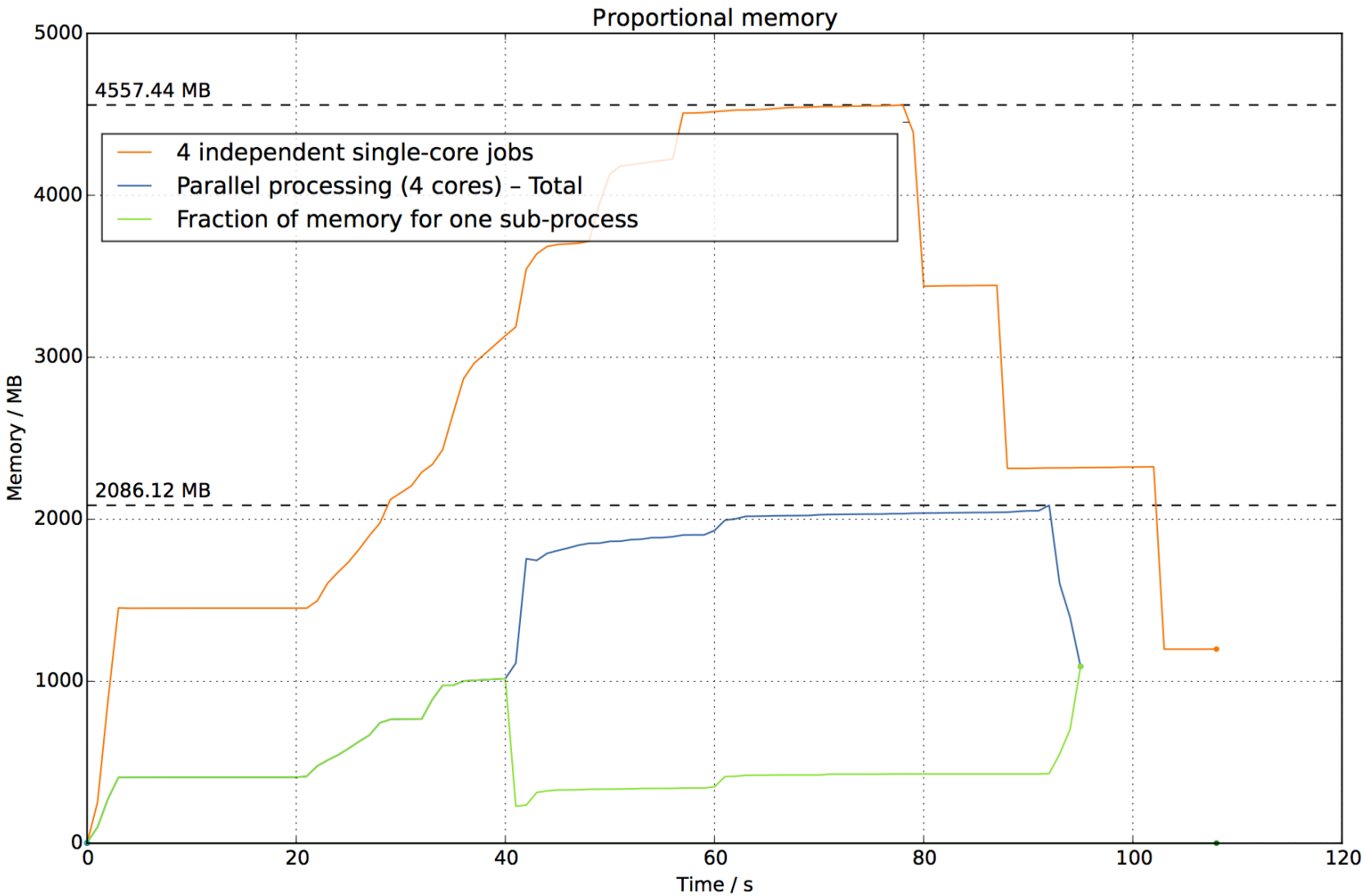


Parallel Processing in BASF2

- Belle II is able to run using multiple cores
- fork()-based:
  - reduces memory requirements
  - few thread-safety issues
- Multi-core jobs would be very beneficial for distributed computing
  - Fewer jobs reduces the strain on the distributed system
  - Shorter jobs would allow more efficient back fill on HPC systems and parasitic use of clouds
  - Smaller memory footprint per core



Parallel Processing Memory Reduction



Simulation + Digitization

- Belle II is using Geant4.10.1.2
  - Default BASF2 physics list is FTFP_BERT
  - Geometry parameters are being migrated to the conditions database
  - Three geometries:
    - Designed geometry is available for all sub-detectors
    - Displacement geometry is the difference between designed and actual
    - Mis-alignment geometry for subtle shifts outside of Geant4

- Magnetic Field:
  - In MC 5, the B field is constant at 1.5T
  - In MC 6, a 3D B field was made available

- Digitization is available and managed by each sub-detector group

- Validation
  - Simulation histograms are added to the basf2 validation package
  - Variable monitored include: particle multiplicity, energy distributions, etc

Beam Background

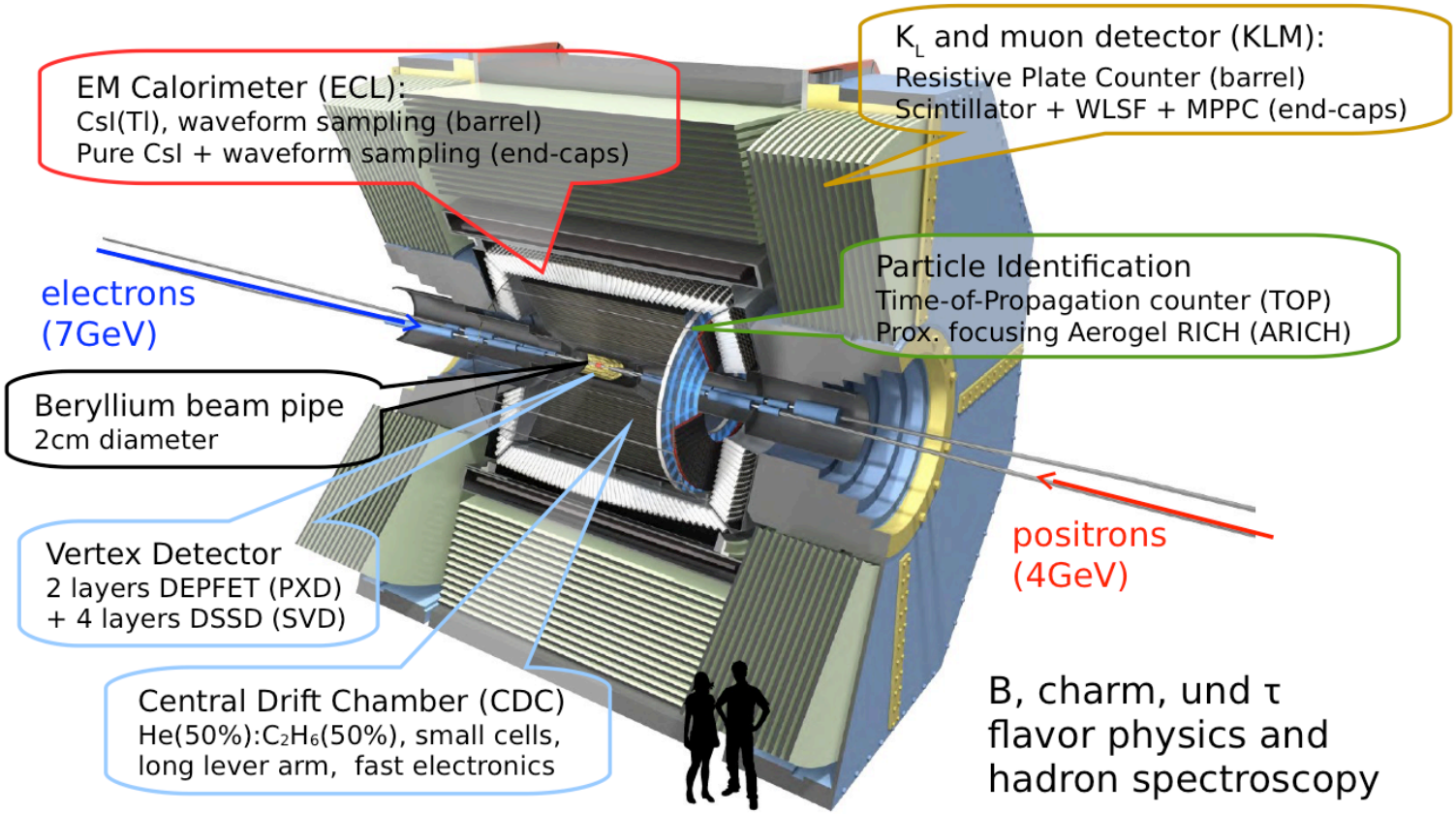
- The beam background is simulation using **Strategic Accelerator Design** (SAD), provided by the accelerator group
  - Simulates transport of particles through the accelerator.
  - If a particle leaves a nominal beam trajectory and collides with the beam pipe or collimator, its 4-momentum is saved to a file
  - The file corresponds to one μs of running at the nominal SuperKEKB luminosity.
  - The file is passed to Geant4 for simulation and deposited energy is stored (SimHits)
  - Backgrounds include: Radiative Bhabha, Touschek scattering, Beam-gas interactions, two-photon QED
  - The backgrounds are mixed with the signal SimHits

- Currently working on background overlay using random trigger events

Belle II Detector

- For more details please see Peter Lewis's talk titled *"Status of SuperKEKB commissioning and Belle II detector construction"*

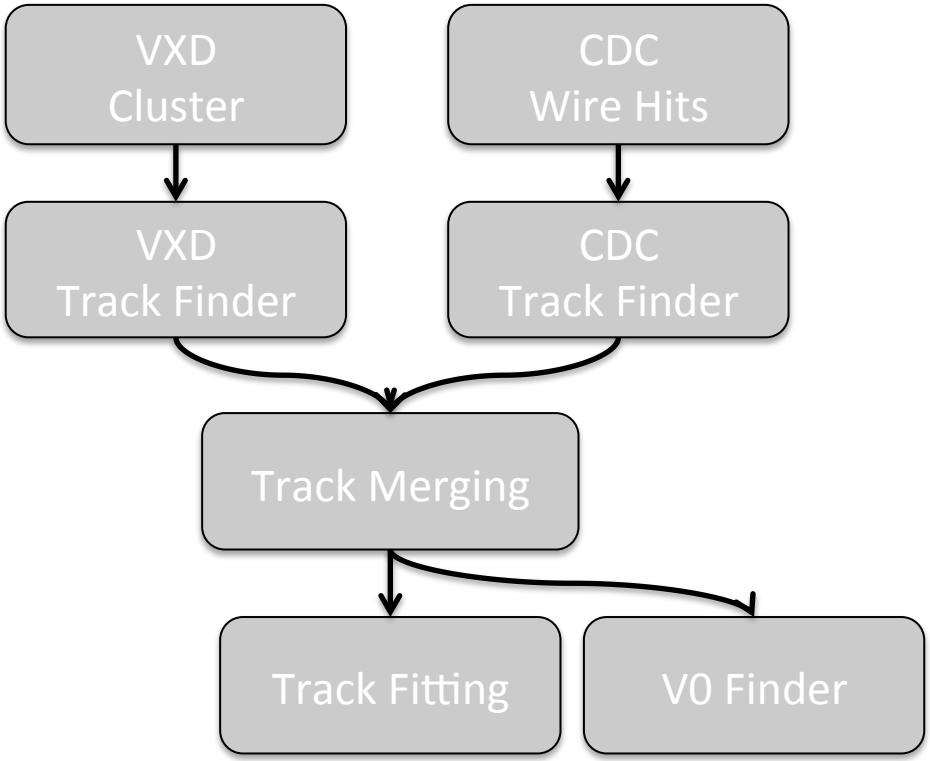
http://indico.cern.ch/event/432527/contributions/1071301/

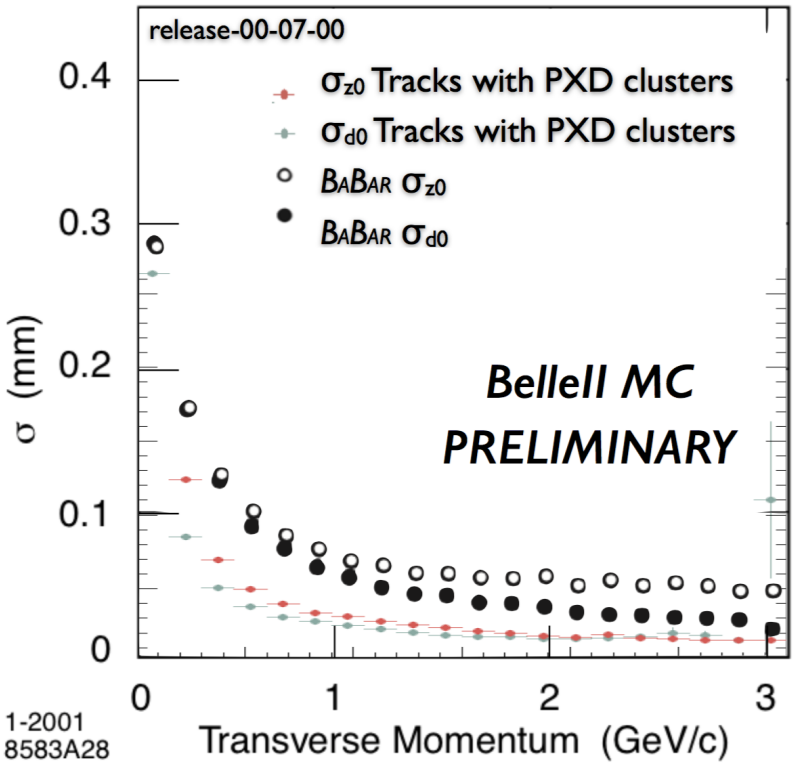


B, charm, und τ flavor physics and hadron spectroscopy

Tracking

- Modular architecture to support re-usability and distributed development
- Real data reconstruction: VXD Test beam and CDC Cosmic Rays

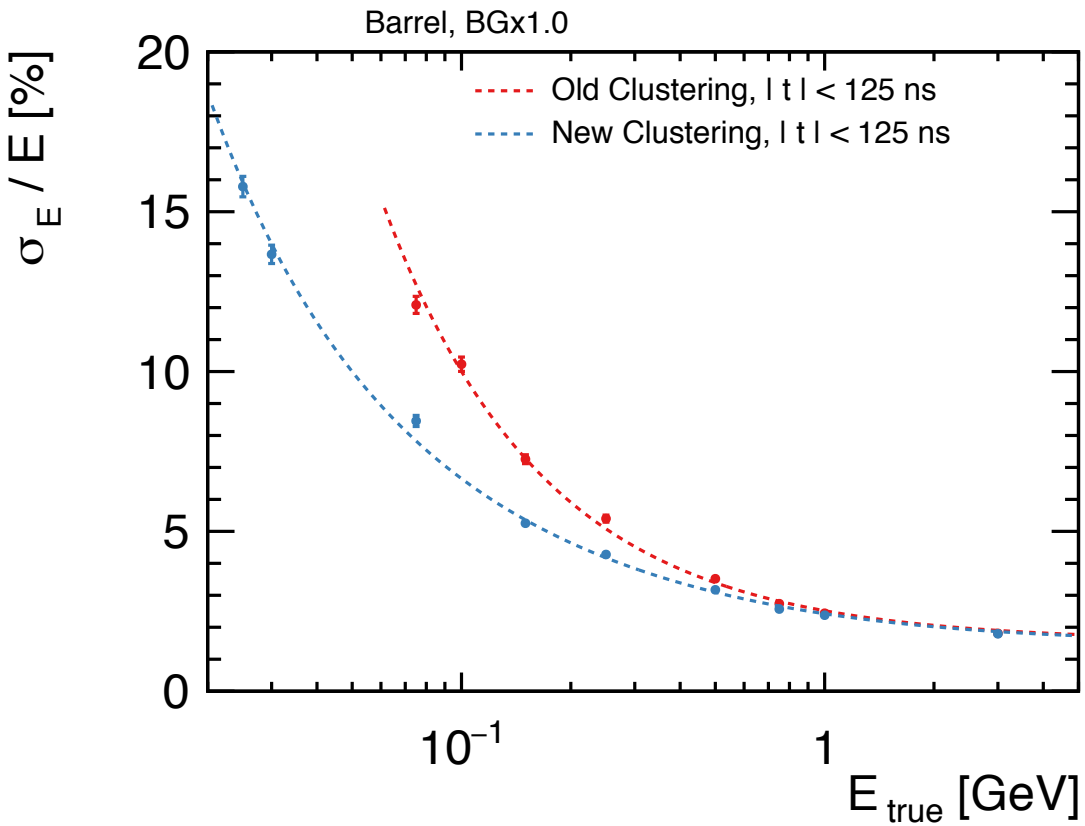




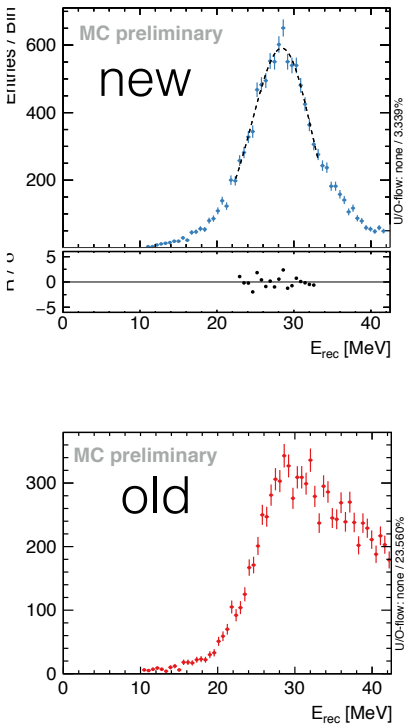
Electromagnetic Calorimeter Reconstruction

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Belle reconstruction worked well for low background but not with high background
- Novel hypothesis based clustering is being investigate
- Different hypothesis will have different number of crystals within a “cluster”



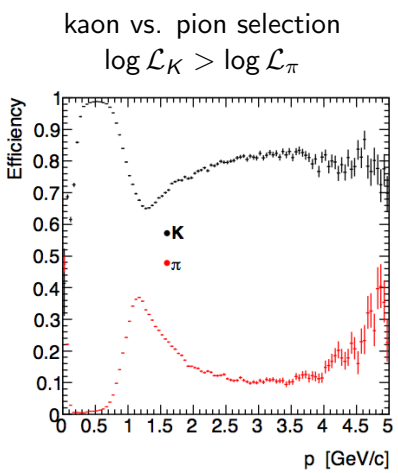
e.g. 30 MeV



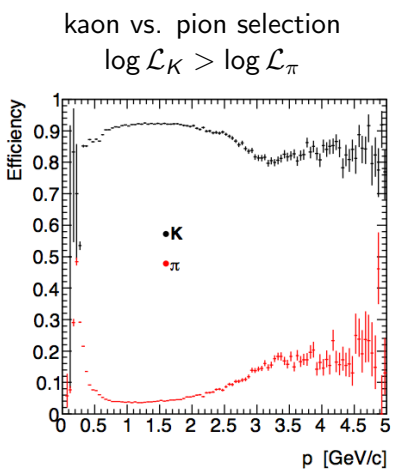
Charged Hadron Identification

- Charged hadron identification primarily from combined information from TOP, ARICH and dE/dx measurements in the CDC and SVD
- Each detector component provides log likelihoods of 6 particle hypotheses: electron, muon, pion, kaon, proton and deuteron

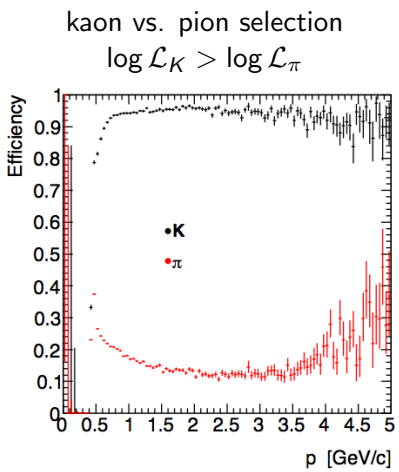
dE/dX only



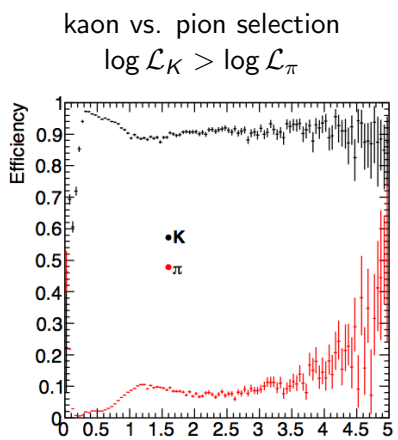
Top only



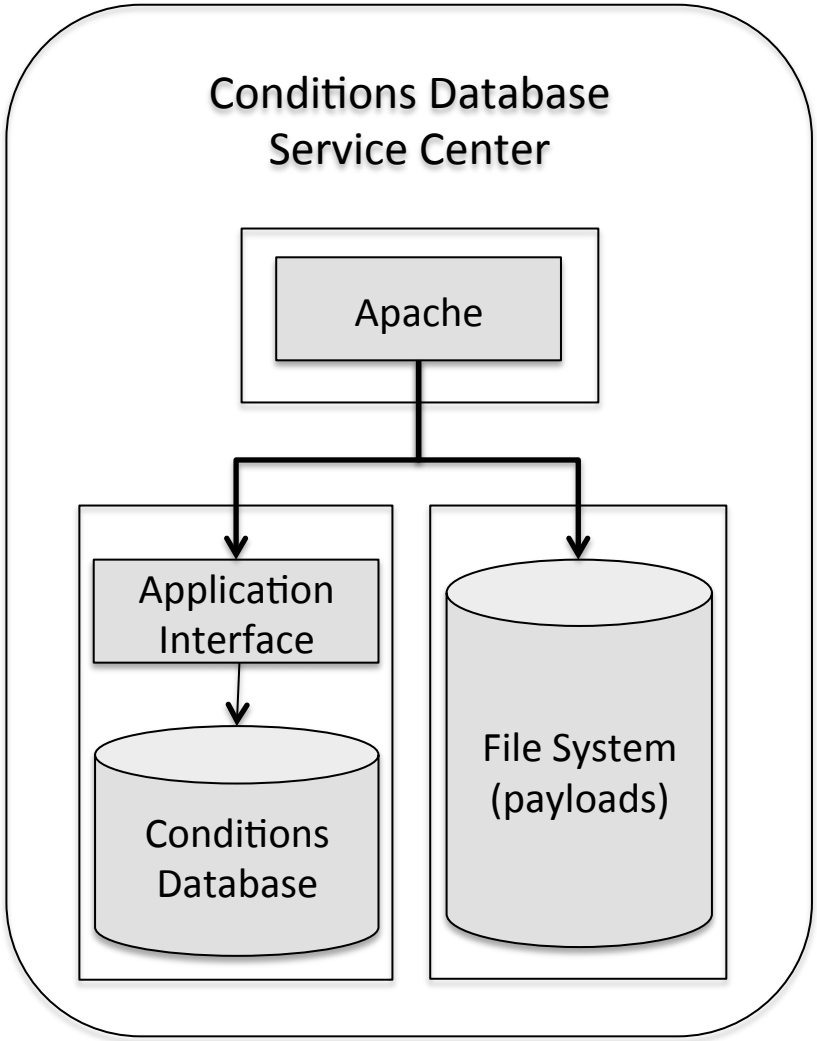
ARICH only



Combined

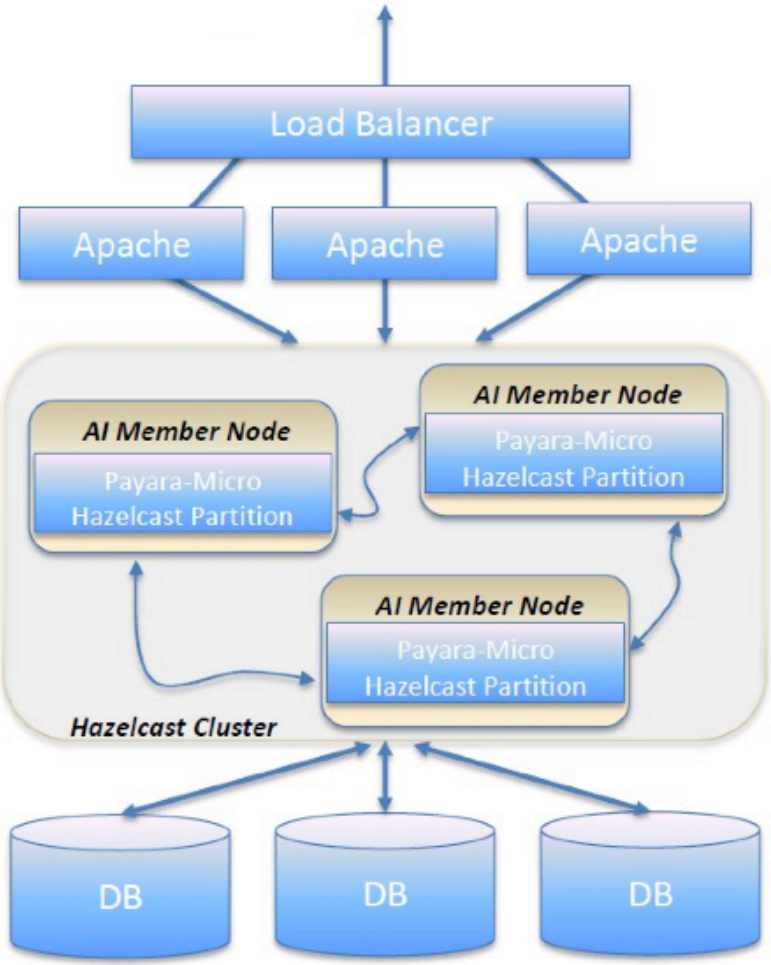


Conditions Database Overview



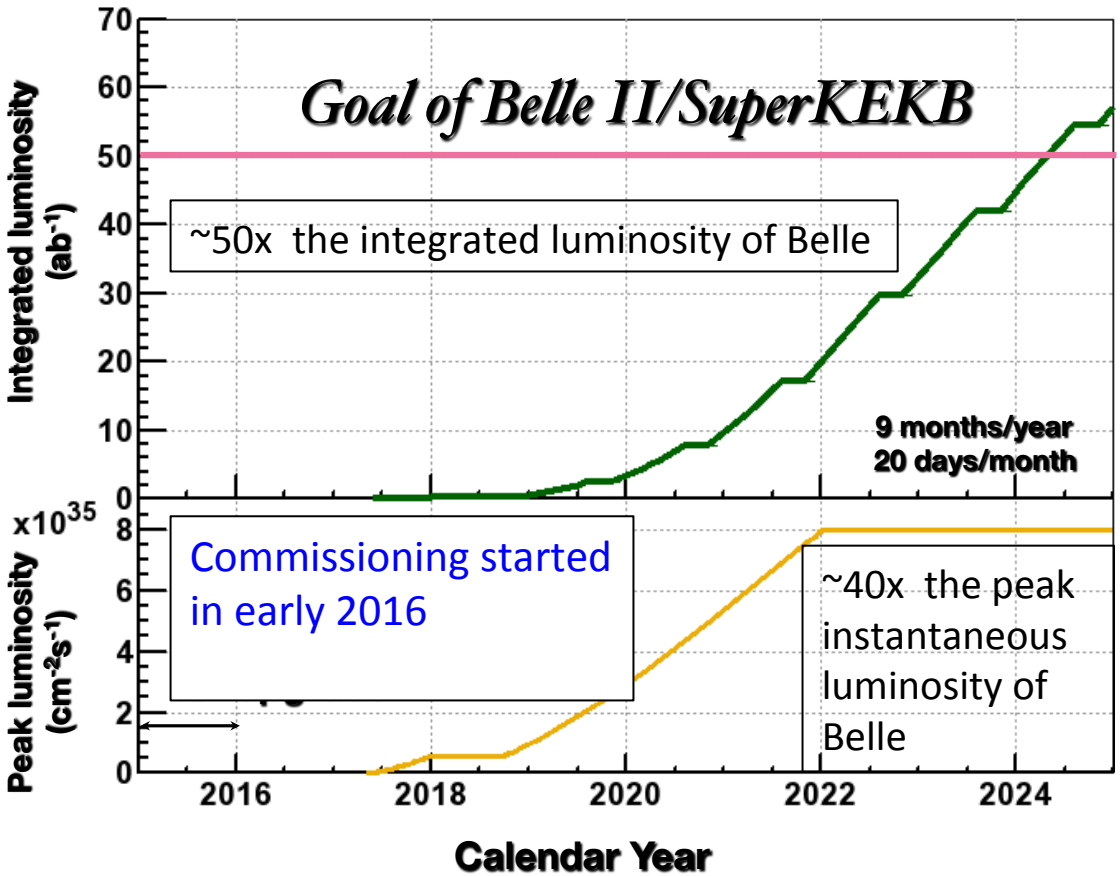
- Provide read/write access to calibration, alignment, geometry, environmental parameters
- Adopted REST API
  - ***Apache*** server
  - Application Interface (***GlassFish***)
  - ***PostgreSQL*** database
  - ***Lustre*** file system
- A global tag is a unique identifier to define a collection of payloads with defined IOVs
- Belle II will use global tags to define processing runs, etc

Scaling the Conditions Database



- Prototype developed using ***OpenStack***
- Use ***Docker*** to develop modular components which allows for quick scaling as needed
- Use ***Swagger*** for automated API documentation
- User ***Payara*** and ***Hazelcast cluster*** for flexible and scalable in-memory data grid solution
- Testing ***OpenStack Trove*** provide redundancy and high availability

Belle II Data Volume & Resources



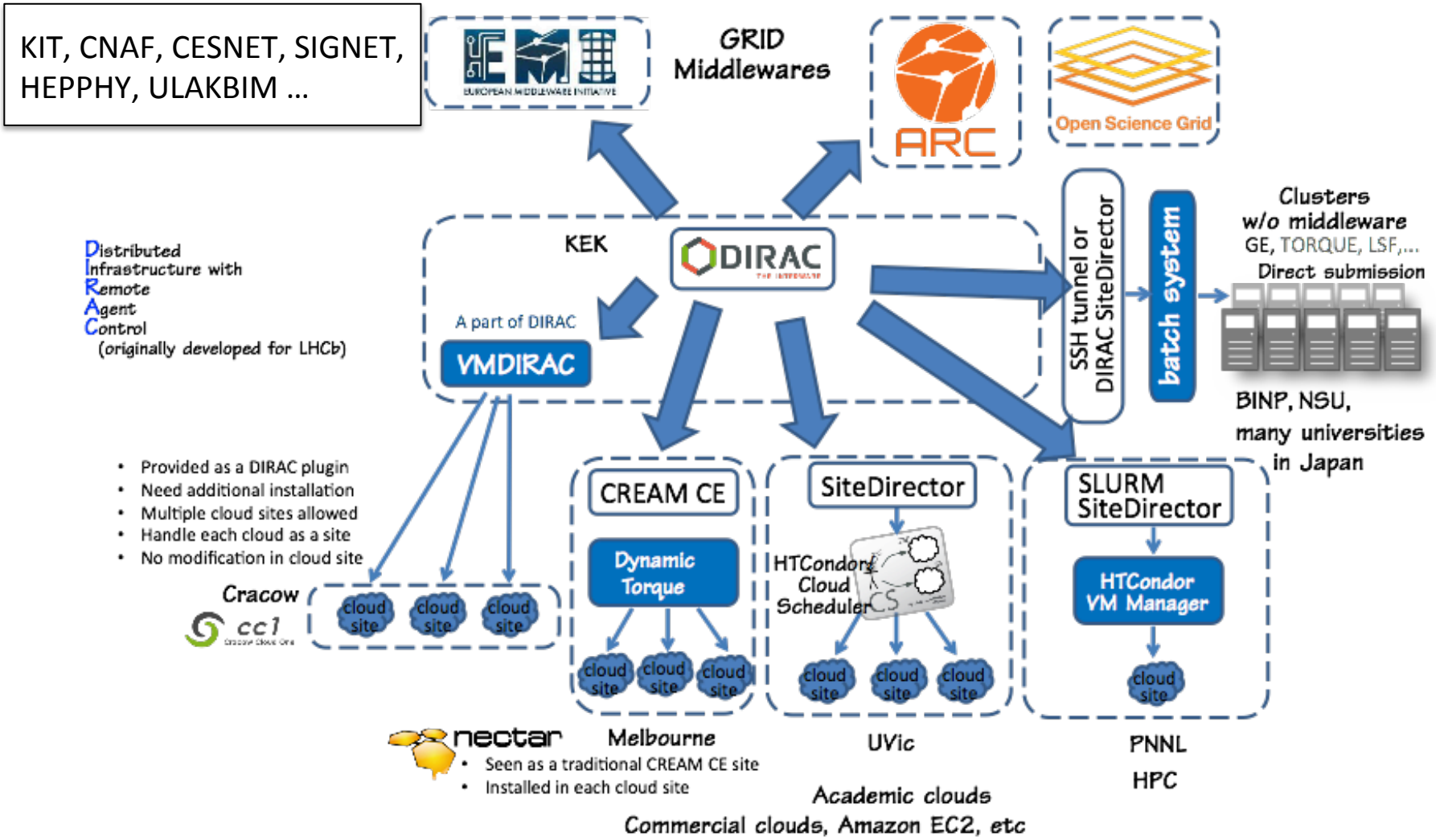
Preliminary

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024
Total Storage (PB)	3	8	10	22	60	116	190	265	341
Total CPU (kHEPSpec)	240	340	475	610	710	880	1060	1420	1640

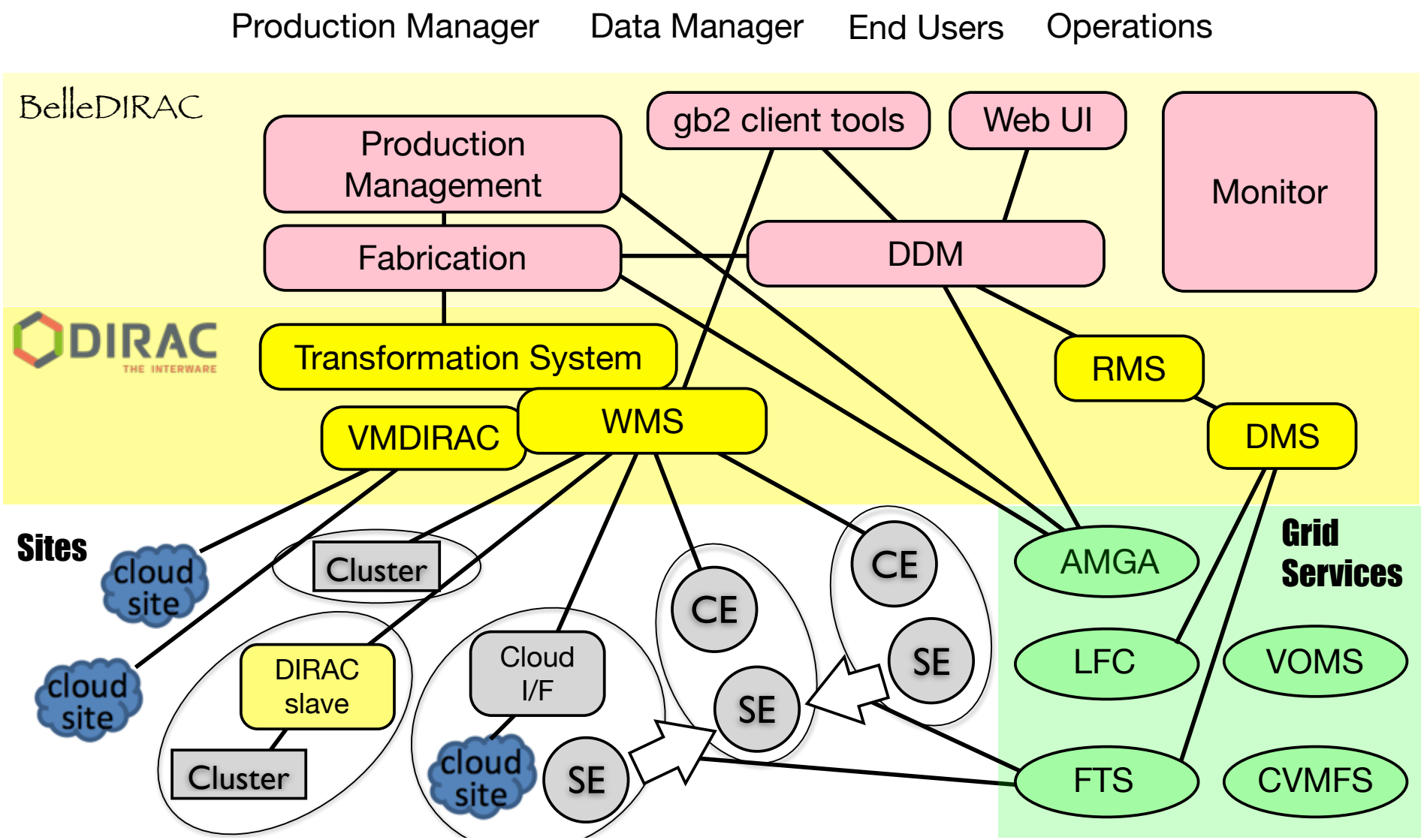
DIRAC (Distributed Infrastructure with Remote Agent Control) **INTERWARE**

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

KIT, CNAF, CESNET, SIGNET, HEPPHY, ULAKBIM …



Belle II Distributed Computing Layers



Core BelleDIRAC Extensions

"Production Manager" (human)

- to define a production : sw release, event type, number of events to produce, …
- and put the parameters into Production Management System

Production Management System

- to create Fabrication instance(s) : simulation, reprocess, skim, merge, …
- and chain them as needed

Fabrication System

- to create and look after jobs, replace failed jobs, verify output of successful jobs
  - simulation jobs can run everywhere, merge jobs can run at the sites with "major" SEs.
- to feed output files to Distributed Data Management System

Distributed Data Management System

- to gather output files to "major" SEs in blocks (important for merge)
- to distribute "final" products over the grid (for further processing / analysis)

Road to full production system

MC3 (2014 May): no Production System

- 2.5 M jobs: **manual submission** by the **shifters** (with a script)

MC4 (2014 Nov): with "prototype" Fabrication System

- ~5 M jobs: **automatic submission** by the system, controlled by **a single system manager**
- Output files uploaded directly from WNs to "major SEs"

MC5 (2015 Aug — 2016 Feb): with improved "prototype" Fabrication System

- ~10 M jobs: automatic submission by the system, controlled by a single system manager
- Output files **transferred by FTS** from production sites to "major SEs"
- **Monitoring and automatic issue detection** for shift tasks and expert investigation

Cosmic ray data replication (2016 Jun ~):

- An agent to register raw data files as they get available on a storage, and make transfer requests
- **Automatic replication of raw data**

Road to full production system (2)

MC6 (2016 Jun): with Fabrication System and DDM

- O(1) M jobs: automatic submission by the system, controlled by a single system manager
- Output file transfers by FTS **controlled by DDM**
- Monitoring and automatic issue detection for shift tasks and expert investigation

MC7 (2016 Nov ~ 5 months): with the Production Management System

- **The software should be well tested by the software group, validated by a production manager**
- Automatic job submission by the system, **controlled by the system**
- Automatic file transfers by the system, **controlled by the system**
- Monitoring of **production progress**
- **Automatised operations** (eg. ggus tickets, downtime, storage health)
- **Tune and improve the system** during the production and afterwards
- **The system will be ready for workflows** other than MC production (raw dta processing, reprocessing, skim, …)

Road to full production system (3)

Scale Tests (to be repeated as needed in between "production" activities)

- To see if we have any limitation in job or file transfer throughputs beyond the current level
- And address the issues found

Cosmic ray data processing (2017)

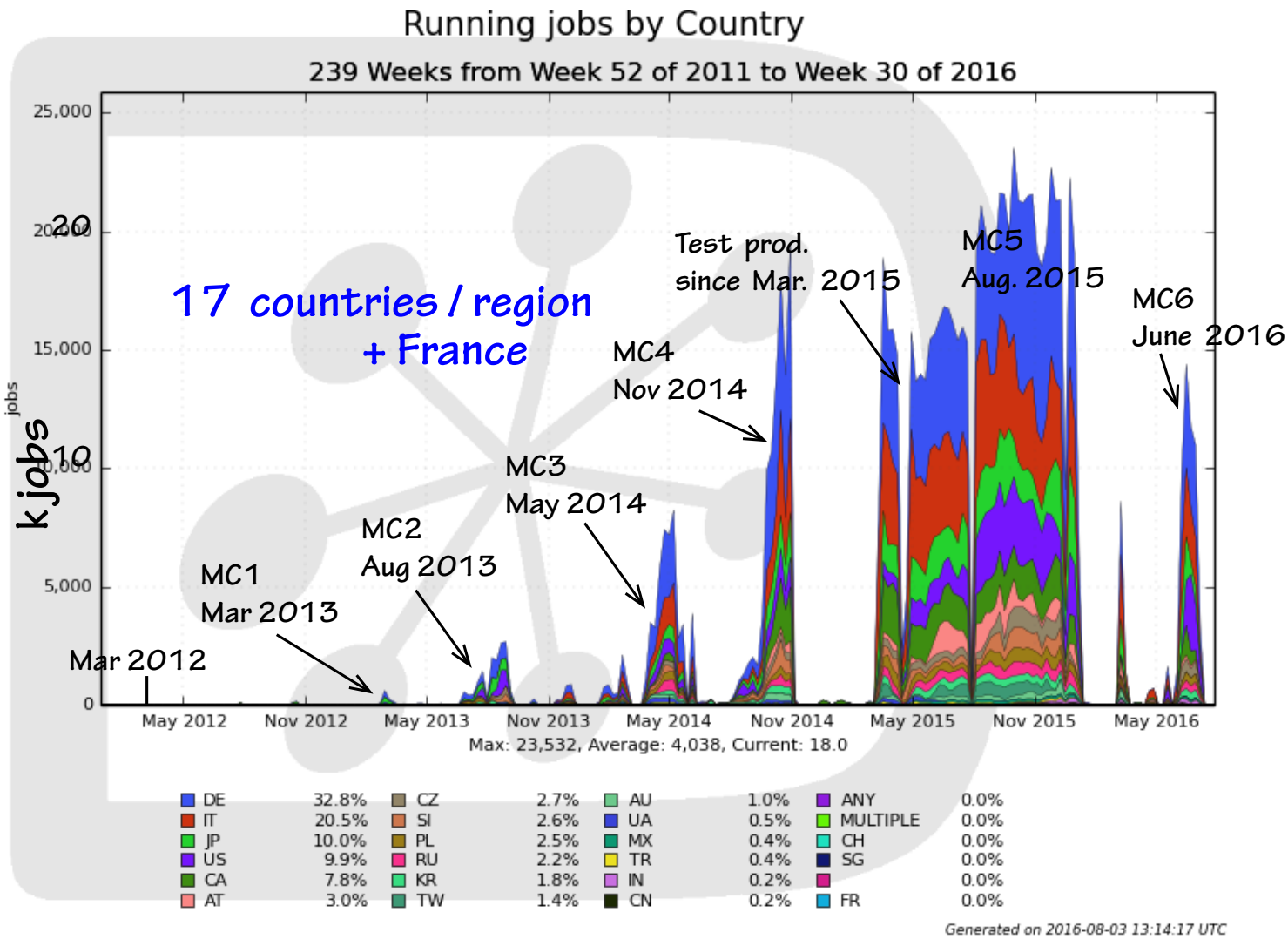
- **Raw data format and reconstruction software need to be ready** and well tested by this time
- **The production system should be ready,** it has been developed not only for MC production, but with other use cases (incl. raw data processing)
- Still, this will be the **first real use case to try raw data processing workflow**

System dress rehearsal (2017): before Phase-2 runs

- To try out the **full chain workflow** from raw data to skim
- Find issues and address them before phase-2 runs

System full dress rehearsal (2018): before Physics runs

Monte Carlo Campaign History



Belle II Networking Requirements

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- In 2014, Belle II was added to the LHCONE network
- International network requirements are based on (*production only*):
  - RAW data
  - mDST from data and Monte Carlo - after data taking and reprocessing
- KEK estimated outgoing (incoming) traffic of 20Gbps (5Gbps) in 2024.
- PNNL estimated maximal incoming (outgoing) traffic 8Gbps (4Gbps)
- European estimated maximal incoming (outgoing) traffic 10Gbps (4Gbps)
- India, Canada and Slovenia will require ~2Gbps traffic
- Other site (Australia) will be interested by a traffic less than 1Gbps

Latest Network Data Challenges

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- DC 1 (2015):
  - KEK ←→PNNL
  - KEK → EU
- DC 2 (2015/2016): LHCONE sites
  - PNNL ←→ EU
  - EU←→ EU
- DC 3 (2016): SINET5 (phase 1)
  - KEK ←→PNNL
  - KEK → EU
- Software stack used:
  - perfSONAR suite
  - SRM storage elements + gridftp servers
  - FTS3 with manual channel configuration

Network Data Challenge Results

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Results of key sites based on the latest data challenges

Source →	KEK	PNNL	DESY	KIT	CNAF	NAPOLI	SIGNET
KEK	N/A	6.3 Gbps	8 Gbps	7 Gbps	7 Gbps	6.6 Gbps	2.5 Gbps
PNNL	3.9 Gbps	N/A	6.6 Gbps	6 Gbps	9 Gbps	8 Gbps	-
DESY	3 Gbps	6.6 Gbps	N/A	8 Gbps	8 Gbps	8 Gbps*	3 Gbps
KIT	3.2 Gbps	4 Gbps*	8 Gbps	N/A	8 Gbps	6 Gbps	3 Gbps
CNAF	3.8 Gbps	8 Gbps	10 Gbps	6 Gbps	N/A	8 Gbps*	3 Gbps
NAPOLI	3 Gbps	3 Gbps*	3 Gbps*	3 Gbps	3 Gbps*	N/A	3 Gbps*
SIGNET	0.8 Gbps	0.6* Gbps	5 Gbps	2 Gbps	5 Gbps	2 Gbps*	N/A

Networking Status and Plans

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- **Current Status**
  - Network data challenge verify that:
    - KEK→PNNL requirements are satisfied until 2019
    - KEK outgoing traffic appears to be limited to ~3-4Gbps
    - PNNL→EU requirements are satisfied
    - EU ←→ EU requirements are satisfied
  - Next data challenge will test new KEKCC and full LHCONE setup (Fall 2016)

- **Moving Forward (FY16-17):**
  - Integrate networking transfer tools into the Distributed Data Management System
  - Integrate KEK in LHCONE and perform new Data Challenge
  - Update network requirements to include estimation on non-production traffic

Summary

- **Software**
  - Analysis tools are in place
  - Physics feasibility studies are being performed using Analysis tools and the latest Monte Carlo samples
  - Software chain is being exercised with the latest RAW data from: VXD, CDC, TOP, etc.

- **Computing**
  - Prototype production system is available
  - Working on scalability test of each components and overall system
  - Three separate systems: Develop/Validate/Production
  - Developing automated unit testing