Belle II Software and Computing

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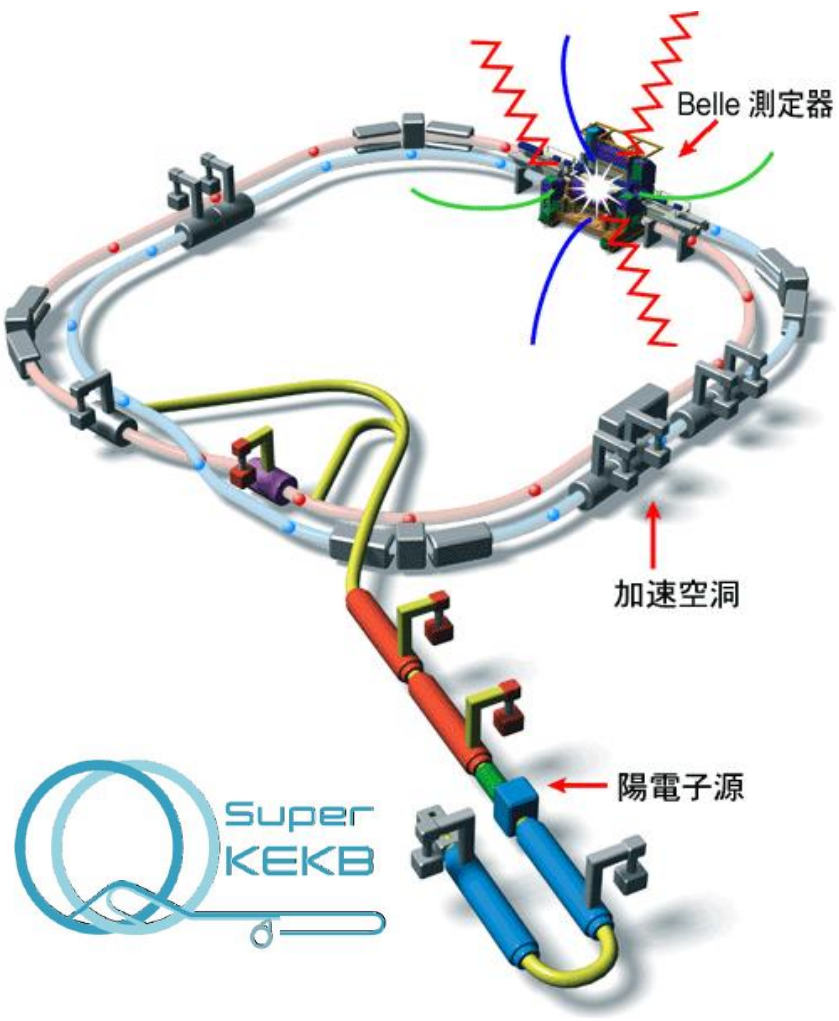
HELMHOLTZ ASSOCIATION

Belle II

DESY

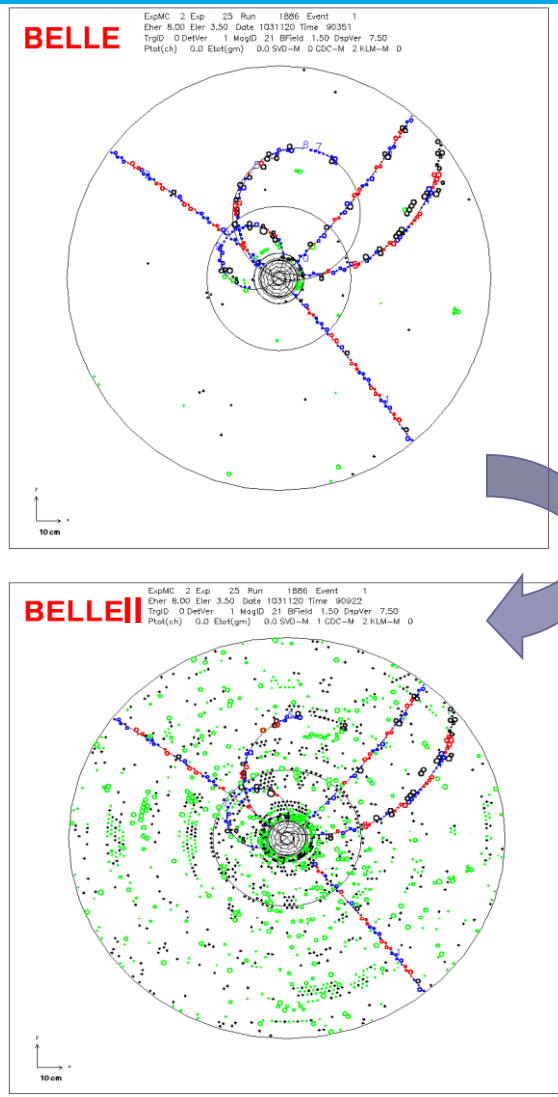
Belle and Belle II



- Belle at KEKB
  - Peak luminosity $2.1\times10^{34}\,cm^{-2}s^{-1}$
  - Collected 1 ab^{-1} of data
  - Confirmation of KM mechanism of CP violation in the SM
  - Precise measurements of CKM elements and angles of the UT
  - Rare B decays and much more
  - Many measurements still limited by statistics
- Belle II at SuperKEKB
  - $\times$40 peak luminosity
  - $\times$50 integrated luminosity

Experimental Challenges at High Luminosity

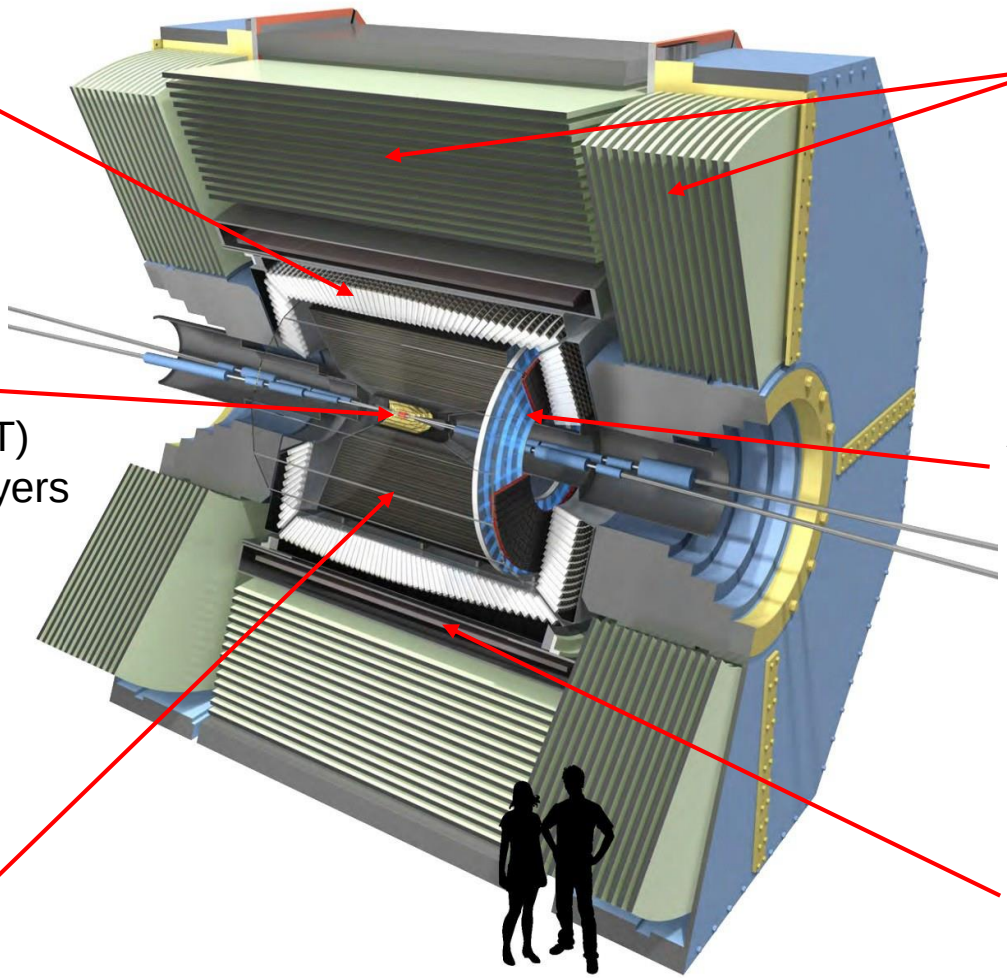
- High background (10-20 times higher than at Belle)
  - Fake hits, pile up, radiation damage
- Higher trigger rate
  - Typical Level1 trigger rate: 20kHz
  - High performance DAQ
- Important improvements
  - Hermeticity for full reconstruction analyses
  - IP and secondary vertex resolution
  - K_S and π^0 identification efficiency
  - Improve Kaon/pion separation



Belle II Detector

CsI(Tl) EM calorimeter:
waveform sampling
electronics, pure CsI
for endcaps

K_L and muon counter:
scintillator + Si-PM for
endcaps



Vertex detector:
2 pixel layers (DEPFET)
4 double-sided strip layers

Aerogel RICH
(forward)

Central drift chamber:
longer lever arm
smaller cell size

Time-of-propagation
(barrel)

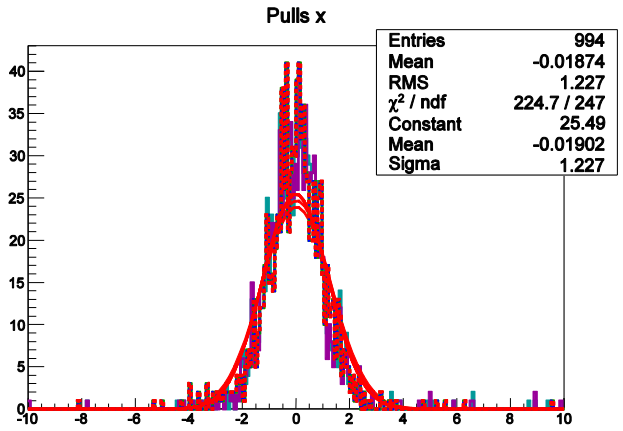
Belle II Software: Outline

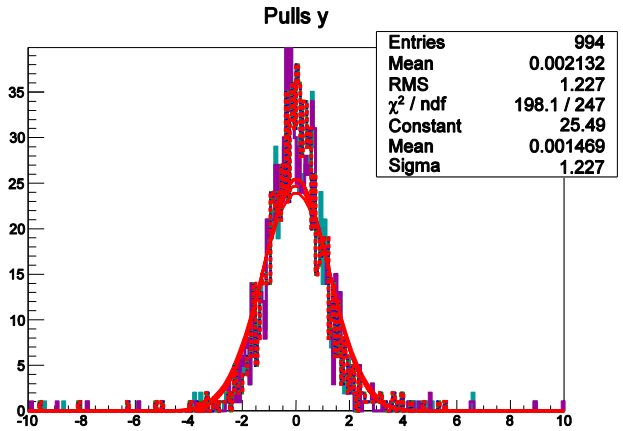
- Code management
- Software framework
- Event display
- Track finding
- Track reconstruction
- Alignment
- Much more not covered, e.g.
  - Database, generators, simulation, detector calibration, ntuple and physics analysis tools

Code Management

- Tools for installation and environment setup
- External software: boost, geant4, root, EvtGen, Millepede II
- Central svn code repository
- Sophisticated build system based on SCons
- Coding convention, automatic style check
- Doxygen documentation, twiki
- Automated builds, tests, and validation
- Issue tracking (redmine)
- Mailing lists

Example of validation plots

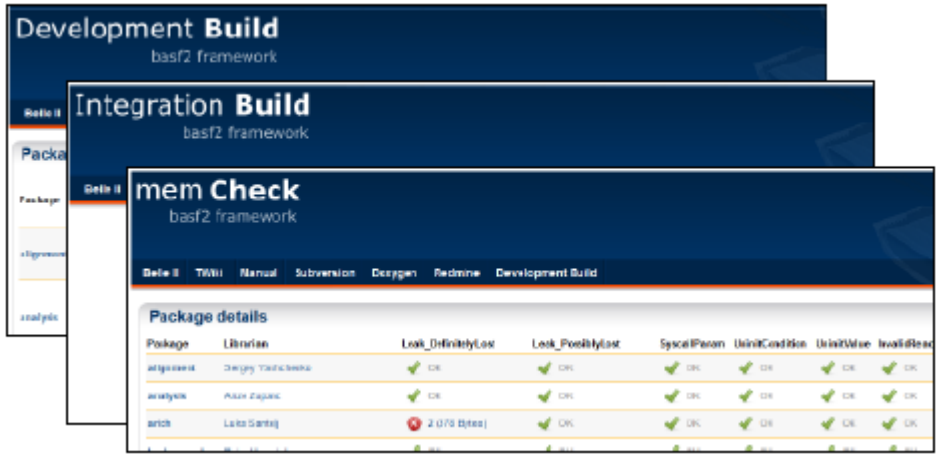




Automatic Builds with Buildbot

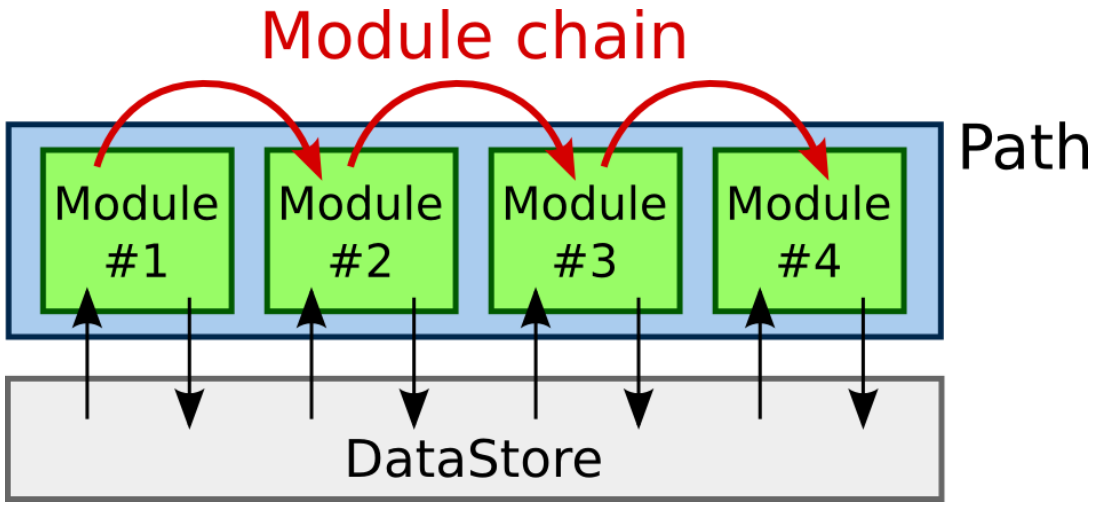
- Compilation on different systems on each commit
- Nightly build:
  - compilation with gcc, icc and clang
  - cppcheck
  - doxygen documentation
  - library dependency check
  - (unit) tests
  - geometry overlap check
  - memcheck
  - validation

→ Email to author or librarian In case of problems



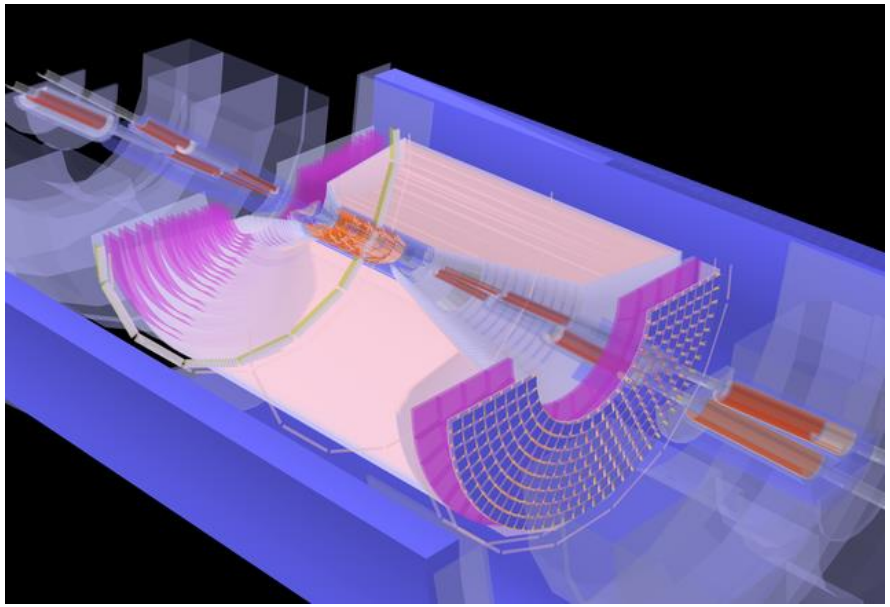
Belle II Software Framework (basf2)

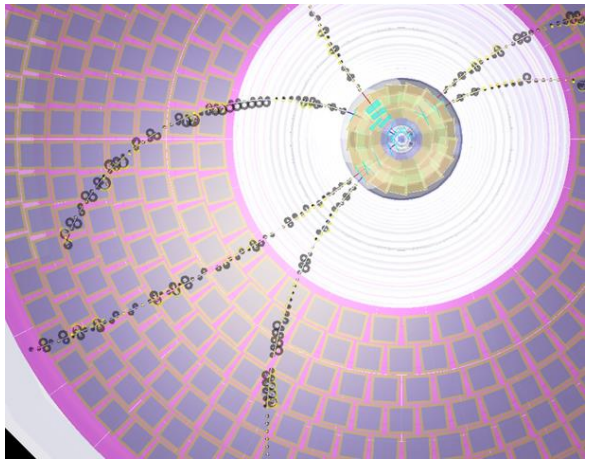
- Written in C++11, steered with Python
- Object-based I/O
- Event-by-event parallel processing
- Python integration allows accessing data for easy plotting, etc. (including interactive usage via IPython)



Event Display

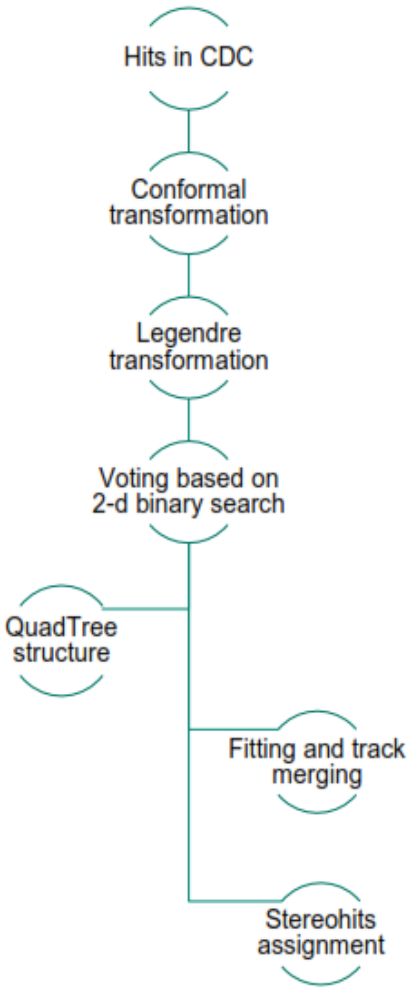
- Event display implemented as basf2 module
- Uses ROOT EVE framework
- Display different data levels
  - MC particles and hits
  - Track candidates
  - Reconstructed objects
  - Custom data (for debugging)
- Successfully used for DESY beam test (online and offline)

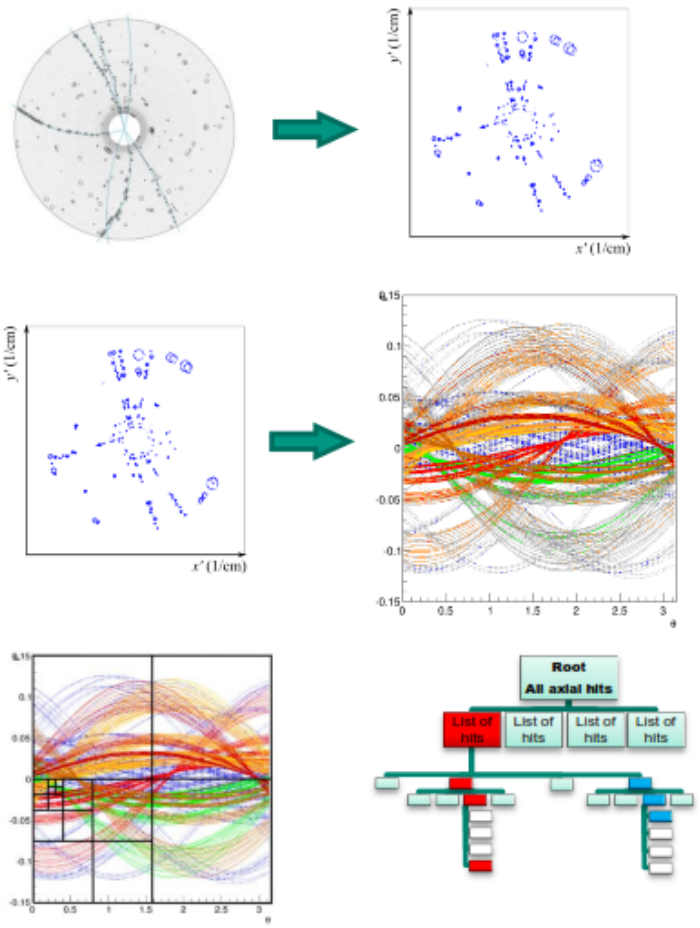




Track Finder based on Legendre Transformation

Chain of the method

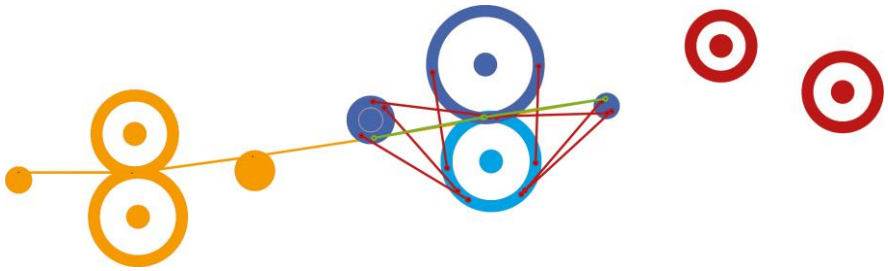




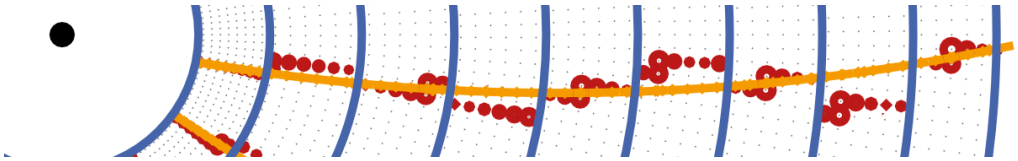
> First tests with Monte Carlo done

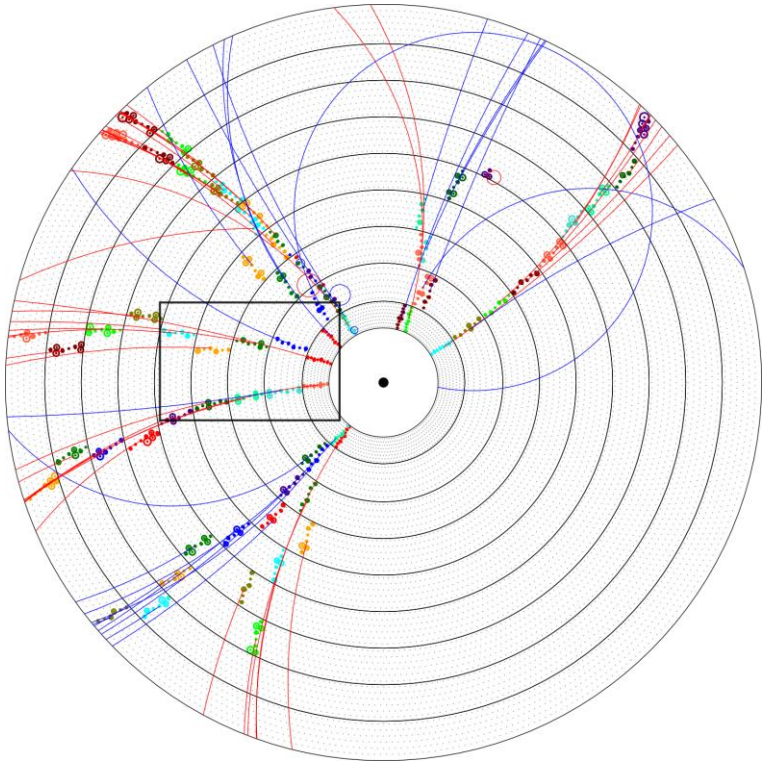
Cellular Automaton Track Finder

> Combine hits to segments limited by superlayer bounds



> Combine segments to tracks





> Preparation to CDC tests with cosmic rays
> First tests with cosmic Monte Carlo done

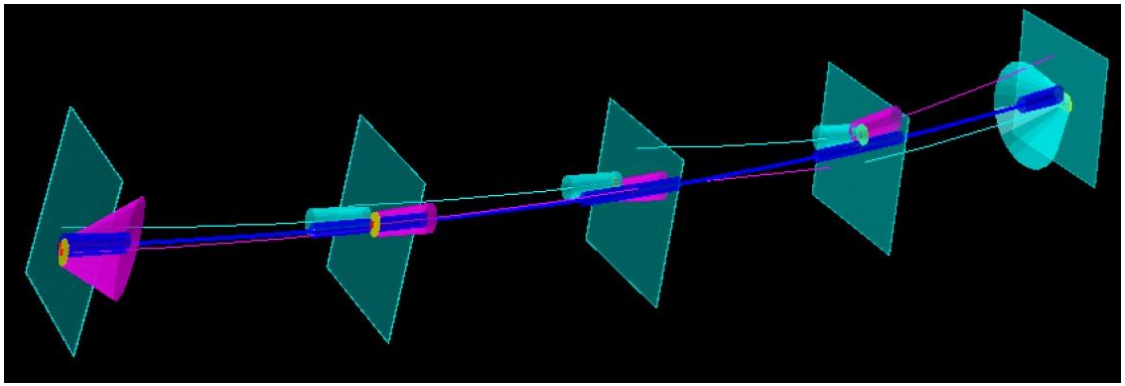
GENFIT: A Generic Track Reconstruction

- Modular track fitting framework
- Suitable for wide variety of experiments and detectors
- Interface to vertex finding framework RAVE
- Interface to alignment code Millepede II
- Open source C++ code (sourceforge.net/projects/genfit)
- Originally developed in the PandaROOT framework (NIMA 620, 2-3, 1121 Aug. 2010, p. 518-525)
- Major update (GENFIT2) based on experience in Belle II
- Large user community (Belle II , PANDA, GEM-TPC, …)

GENFIT: Modular Design

- Measurements
  - Strip, pixel, wire, space points
  - Provide (virtual) detector planes and measurement coordinates and covariance projected into that plane
- Track representations
  - Track parameterization
  - Extrapolation through material and magnetic field
  - Particle hypothesis

- Track
  - Contains measurements (can be from different detectors)
  - Can be fitted with several track representations simultaneously
  - Start values for fit needed, e.g., from track finding



Alignment: Millepede II and General Broken Lines

MPII

V. Blobel, NIM A, 566 (2006), 5-13

PHYSICS AT THE TERA SCALE Helmholtz Alliance

- Calculates corrections to initial values of global alignment and calibration parameters
  - With block matrix algebra can be reduced to a system of the size of the number of global parameters
  - Obtain all global parameters keeping the correlations due to all the tracks, complete covariance matrix from all local track fits is required

GBL

C. Kleinwort, NIM A 673 (2012) 107

- Fast global track refit taking multiple scattering into account
  - Determine the complete covariance matrix of all track parameters
  - Additional local or global parameters can be added

Belle II

DESY

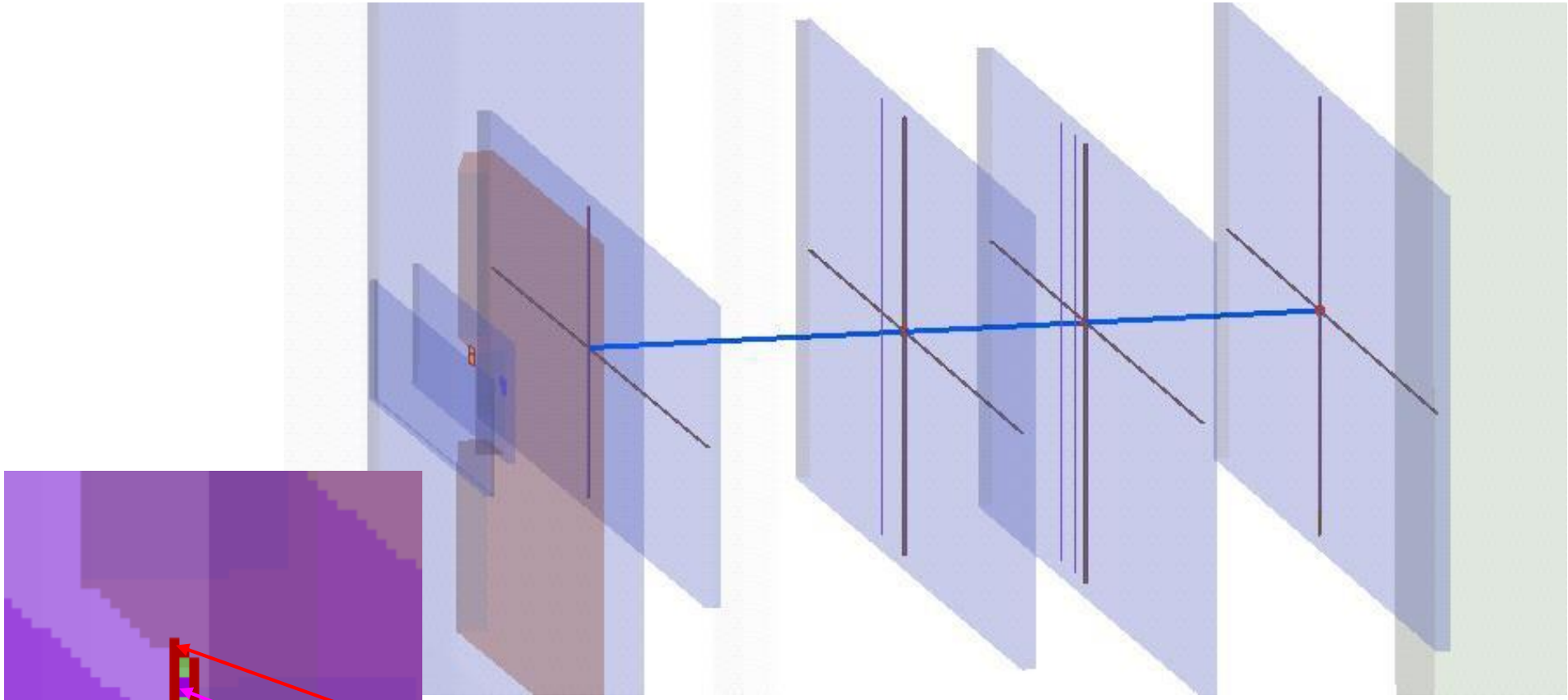
Status of Alignment

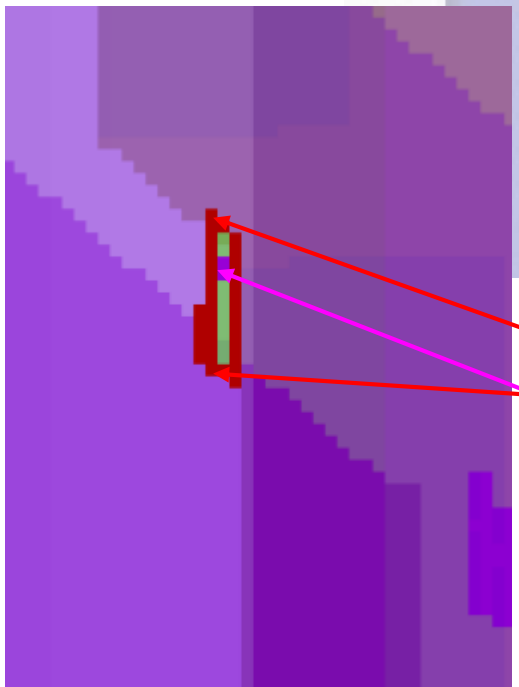
- Alignment using Millepede II and GBL track fit
  - Integrated to the Belle 2 software: Millepede II as external, GBL as a part of GENFIT
  - Tested on Monte Carlo and DESY test-beam data for VXD, will be tested on cosmic ray data next year for CDC
- GBL fully integrated in GENFIT as a standard and experiment-independent track fit method
  - Any geometry, sensor orientation, material distribution, combination of 1D (strip/wire) and 2D measurements (pixel or combined strips), non-homogeneous B field or no field
- Towards common track-based calibration framework

Beam Test at DESY

- VXD common beam test at DESY in January 2014 (4 weeks) and several weeks of the beam-test preparation since October 2013
- Small sector of the close to final prototype detectors and ASICs
  - 2 PXD half ladders + 4 SVD single module layers
- Complete VXD readout chain: HLT, monitoring, event building, PocketDAQ
- Run and slow control, CO2 cooling and environmental sensors developed on a base of EPICS real-time control system
- Illumination with (up to) 6 GeV e^- under solenoid magnetic field (PCMAG)
- Alignment, tracking algorithms, Regions Of Interest (ROI)
- Goal: System integration test including software

Region of Interest in PXD



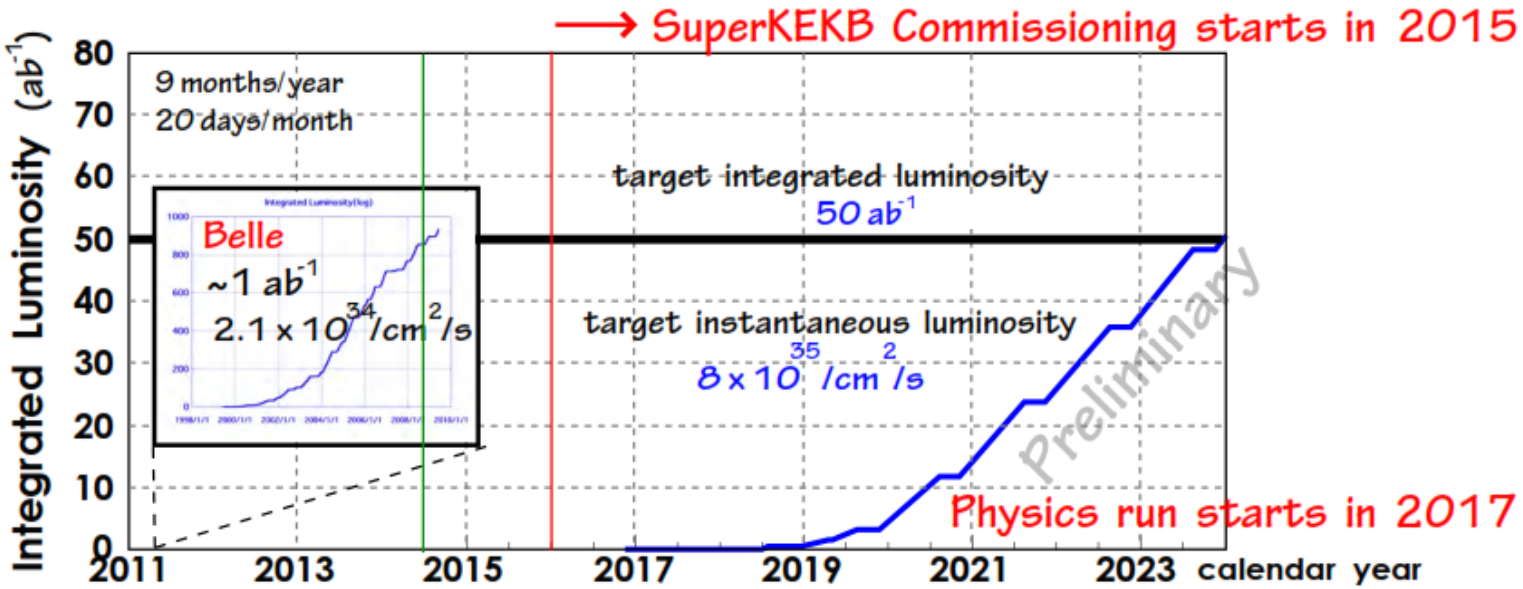


- Tracking using SVD
- PXD ROI extrapolation
- Hit found inside the PXD RO
- More information in arXiv:1406.4955

Belle II Computing: Outline

- Computing Requirements
- Computing Model
- Networking
- Monte Carlo Campaign

Computing at Belle II

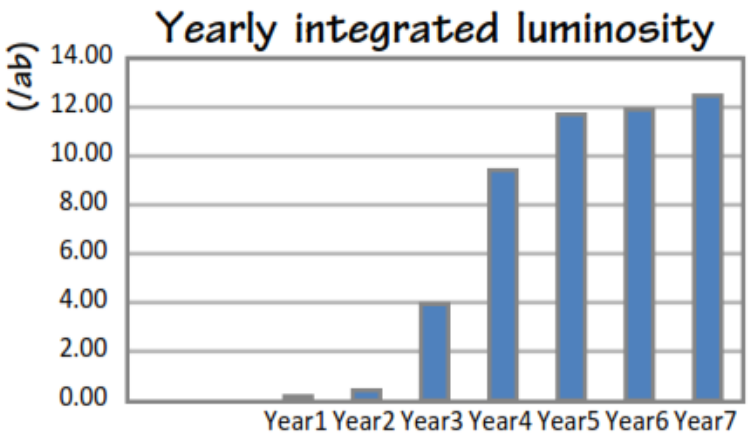


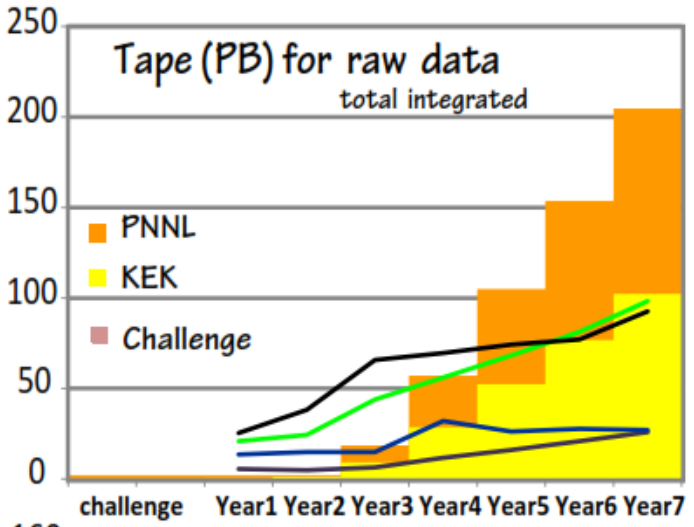
Experiment	Event size	Rate @ Storage	Rate @ Storage
	[kB]	[event/sec]	[MB/sec]
Belle II	300	6,000	1,800
ALICE (Pb-Pb)	50,000	100	4,000
ALICE (p-p)	2,000	100	200
ATLAS	~700	600	400
CMS	~1,000	500	several 100s
LHCb	55	4,500	250

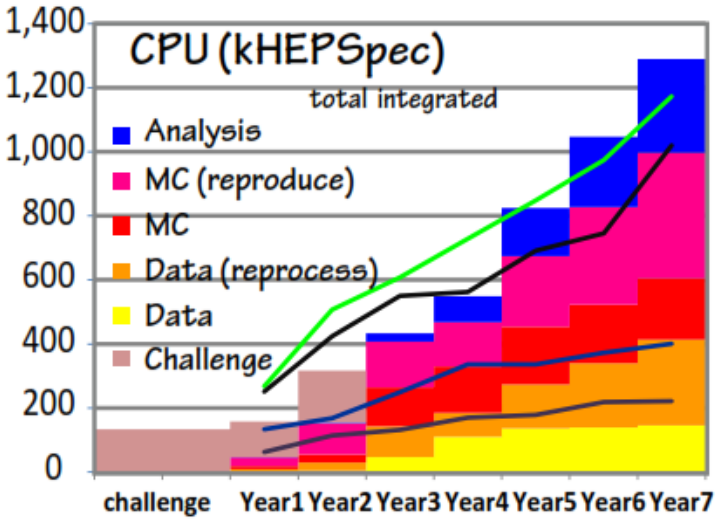
(@ max. luminosity)

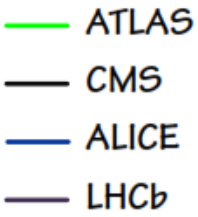
(LHC experiments: as seen in 2011/2012 runs)

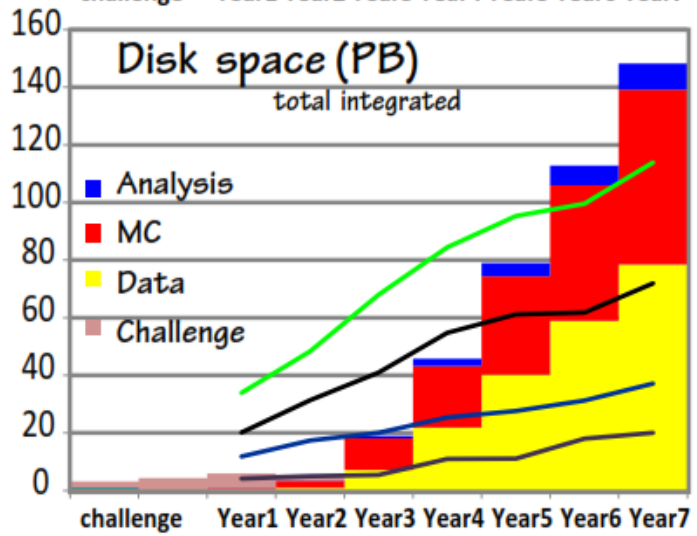
Requirements to Computing





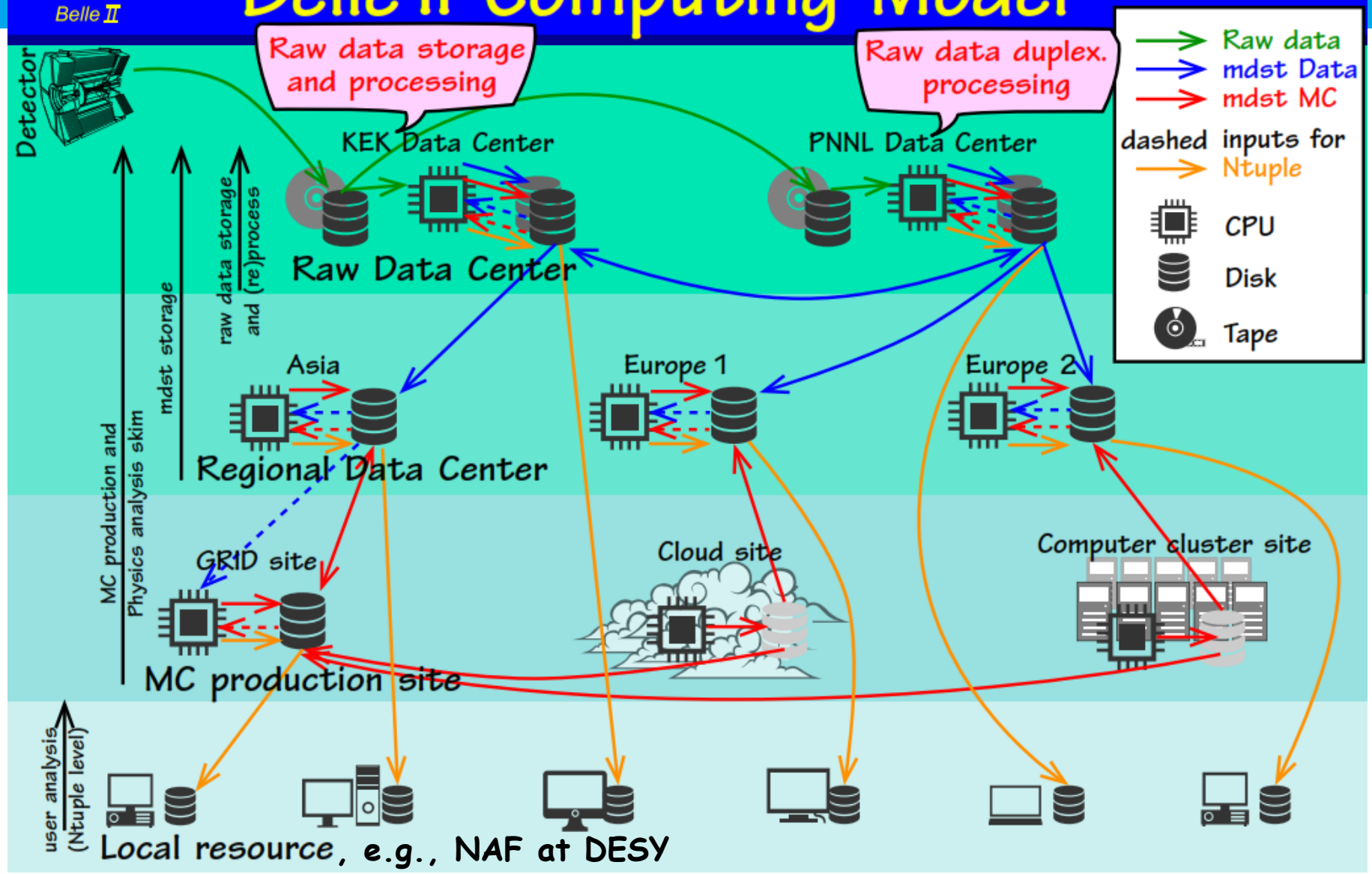




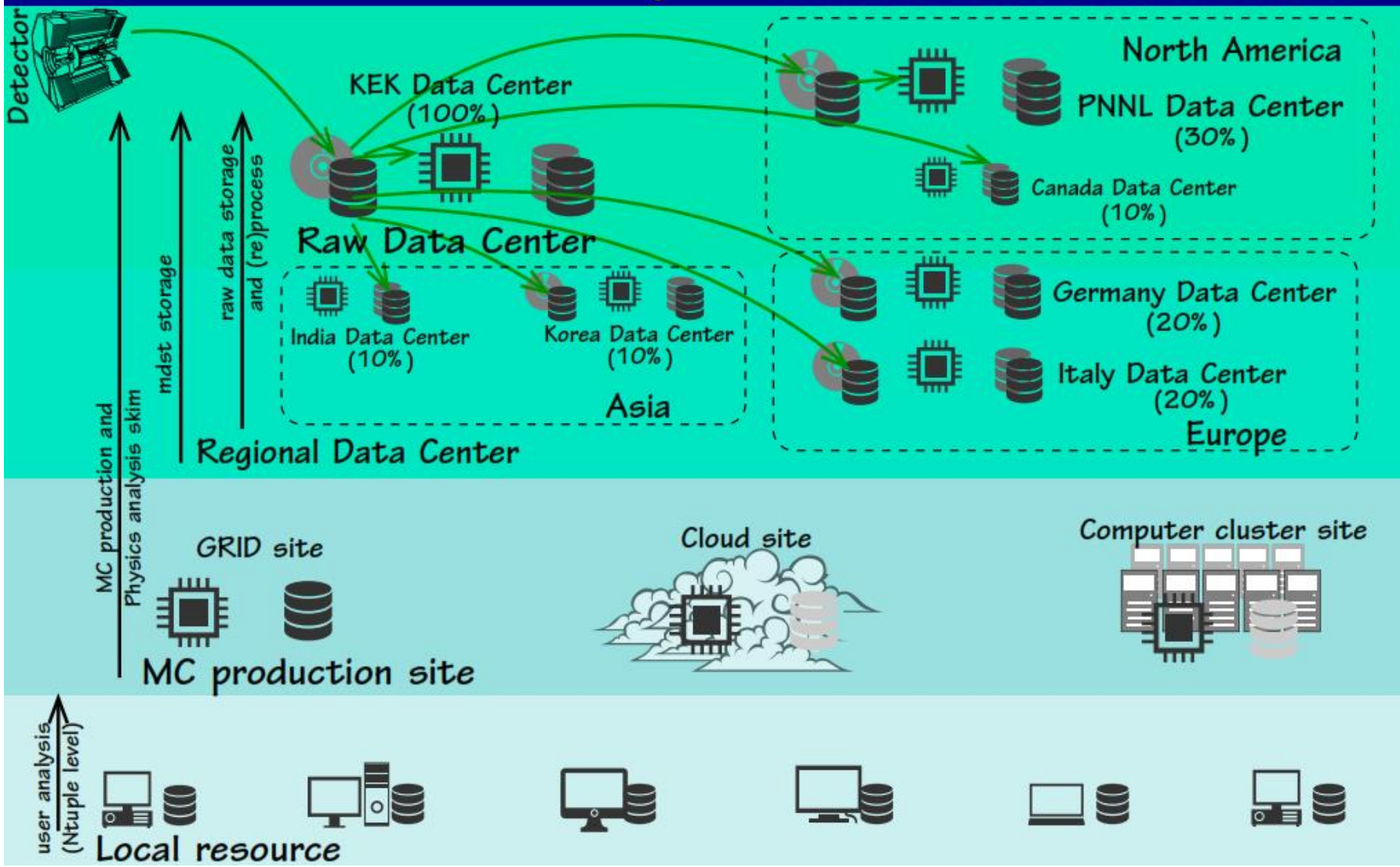


Pledge summary of LHC experiments : http://wlcg-rebus.cern.ch/apps/pledges/summary/

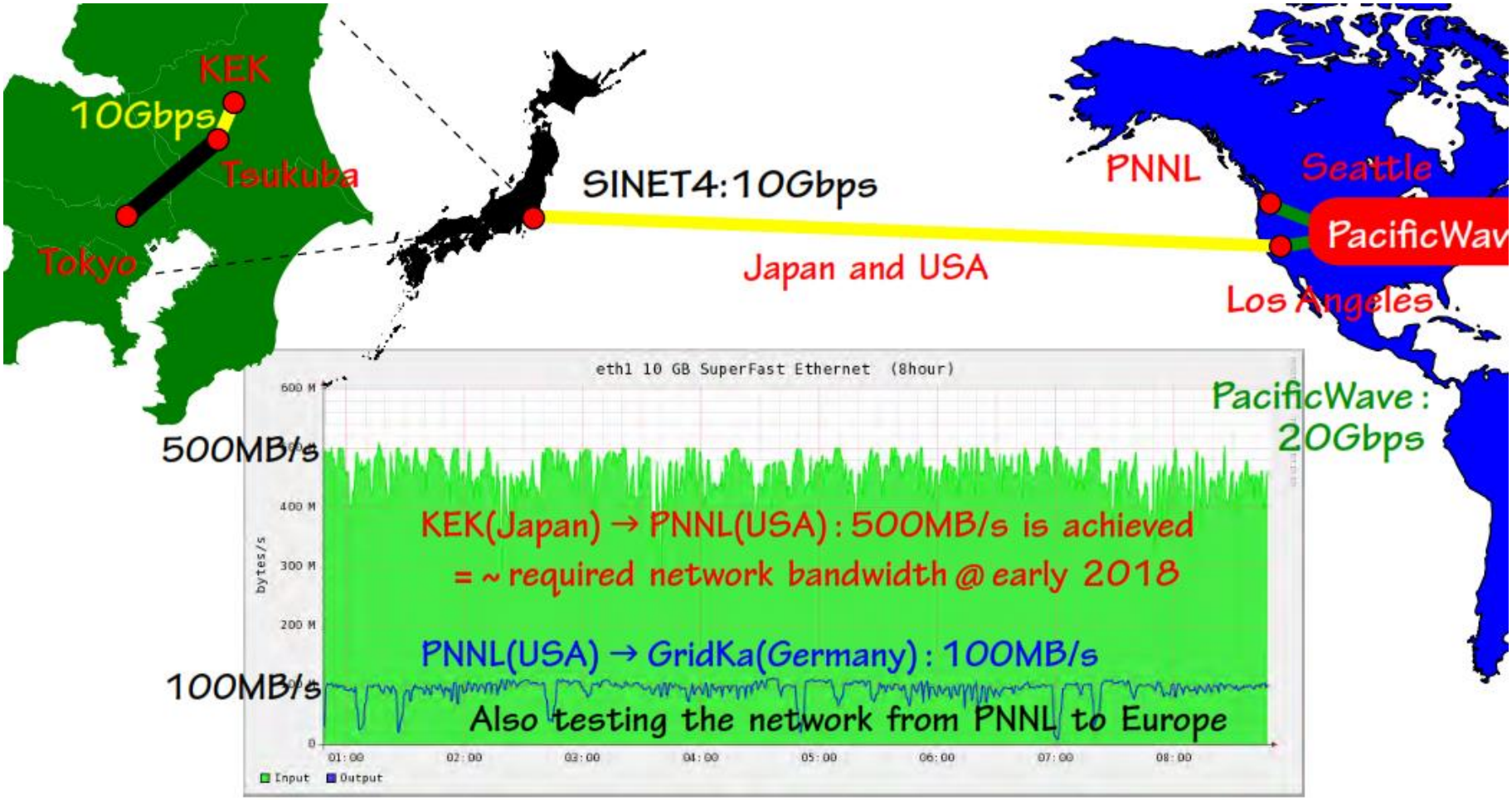
recap. Belle II Computing Model until Year 3



modified Belle II Computing Model after Year 4 (raw data part)



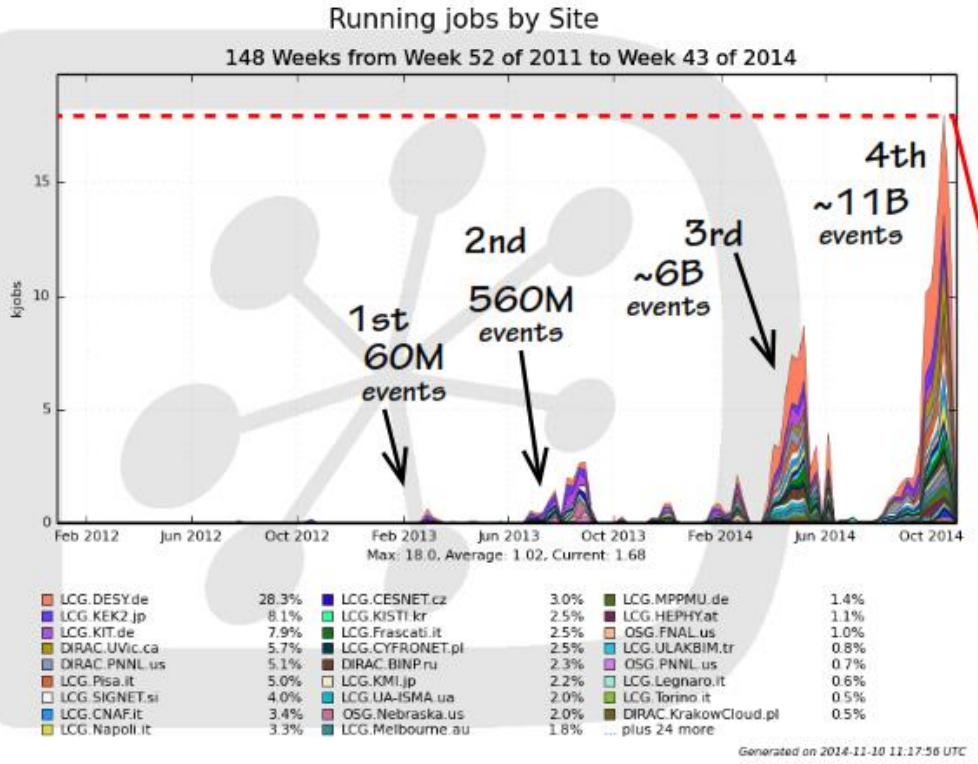
Trans-Pacific Data Challenge



But not enough for the network bandwidth @ middle of Year4 and later (~2GB/s)

We need a 40Gbps - 100Gbps network between Japan and USA

Current Status of Computing



15 countries/regions

Australia, Austria, Canada, Czeck R., Germany, Italy, Japan, Korea, Poland, Russia, Slovenia, Taiwan, Turkey, Ukraine, USA

31 sites

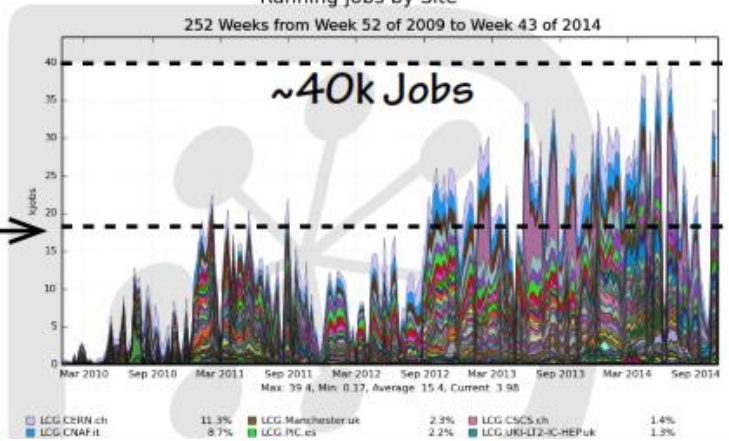
GRID, Cloud, local cluster is available

18k Jobs in 1-day average

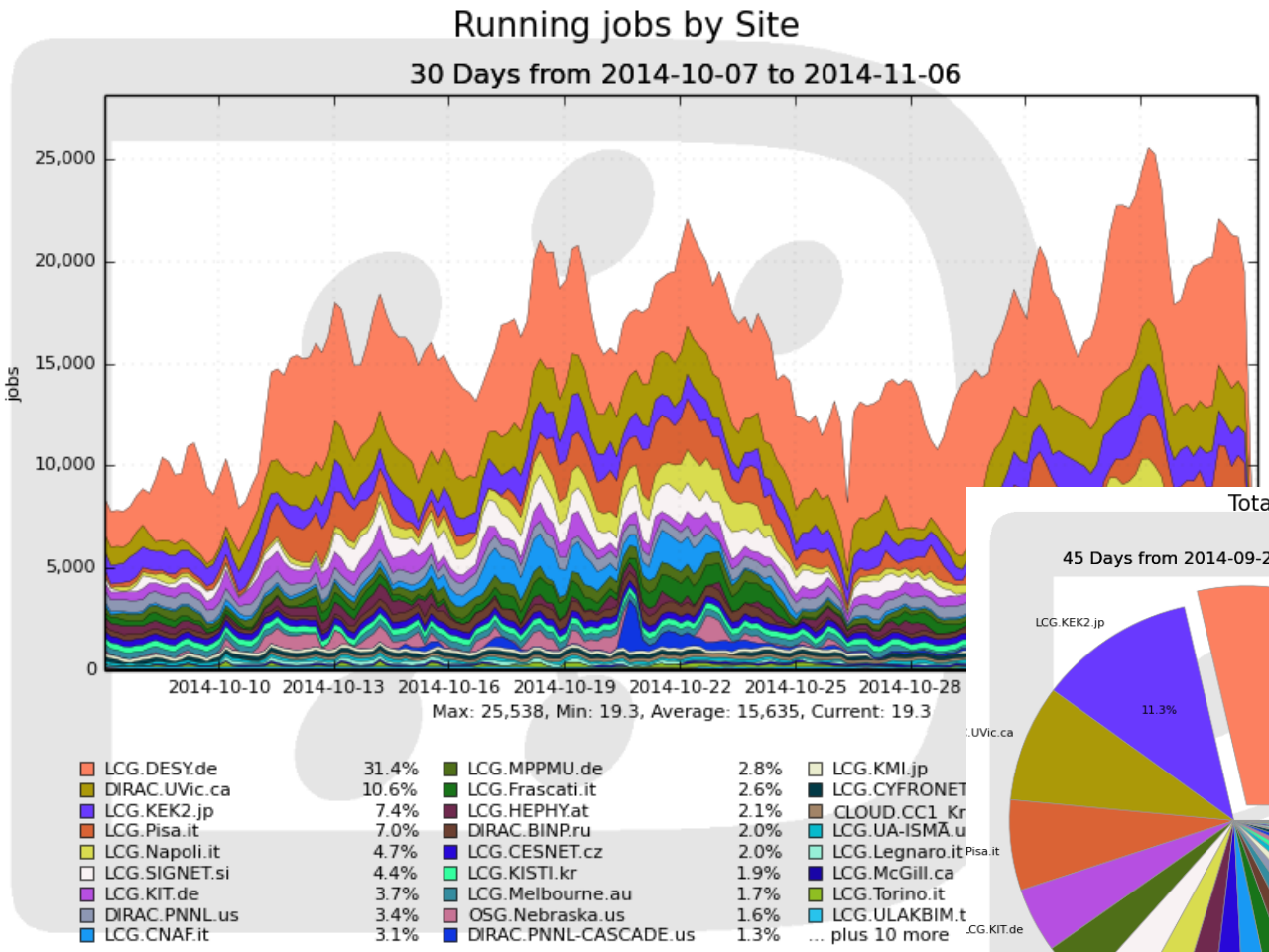
corresponding to 2.6 ab^{-1} in total

Belle II now
18k Jobs

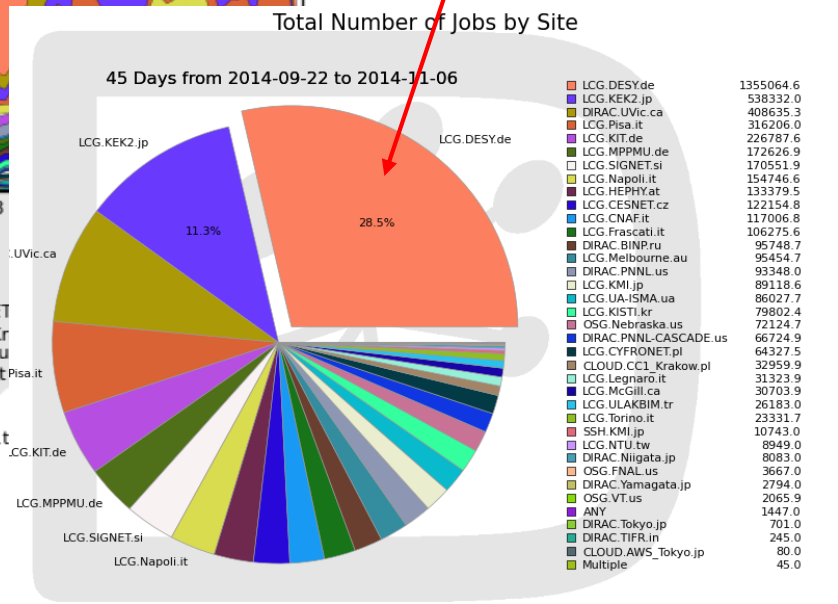
LHCb (~120 sites)



4th Monte Carlo Campaign



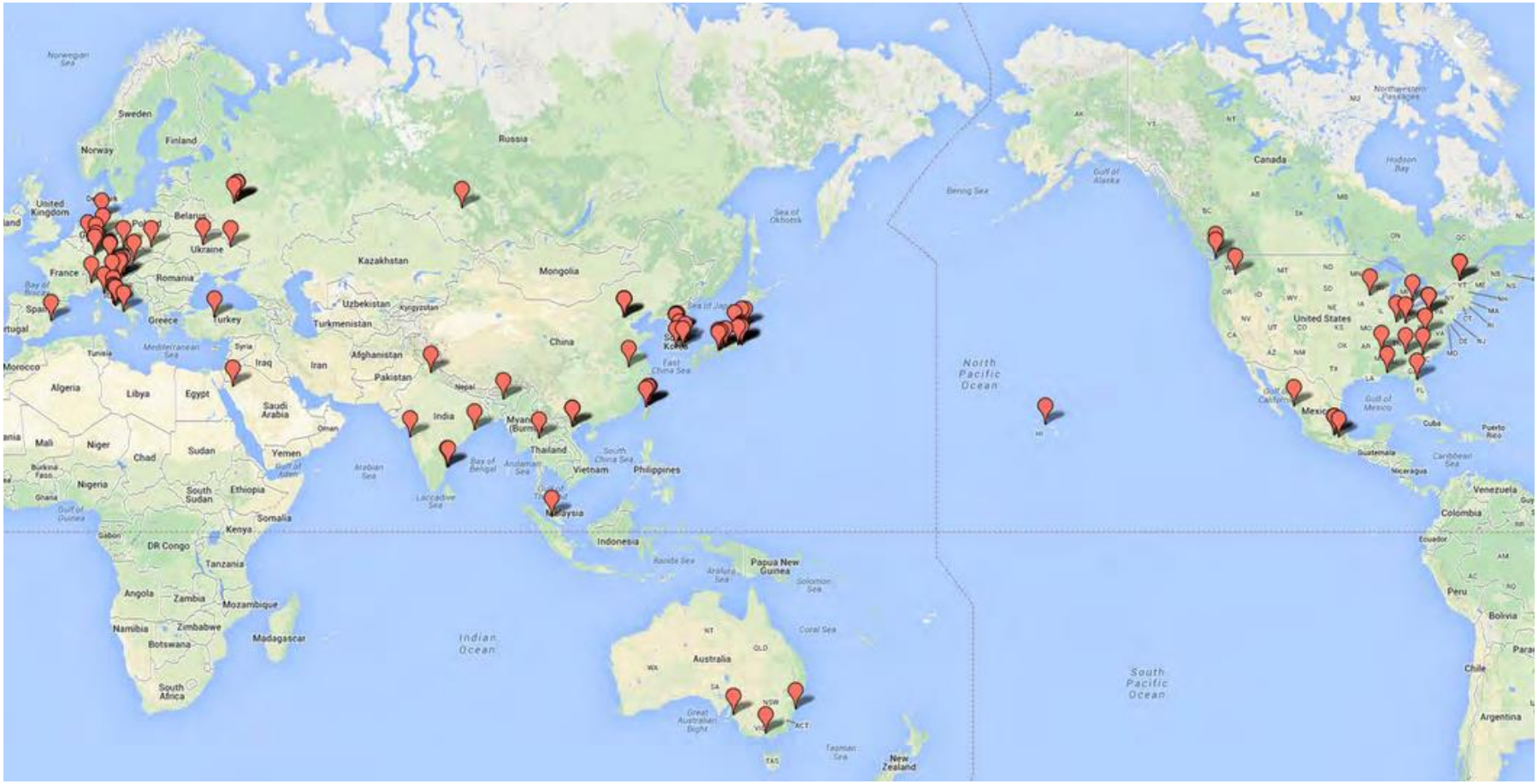
About 30% contribution from DESY



Summary

- Software for Belle II under development
  - Tests with Monte Carlo and beam test data ongoing
- High requirements for computing at Belle II
  - Current achievements promising
- Obvious aim to be ready for data taking
  - Seems to be realistic
- The Belle II collaboration is growing

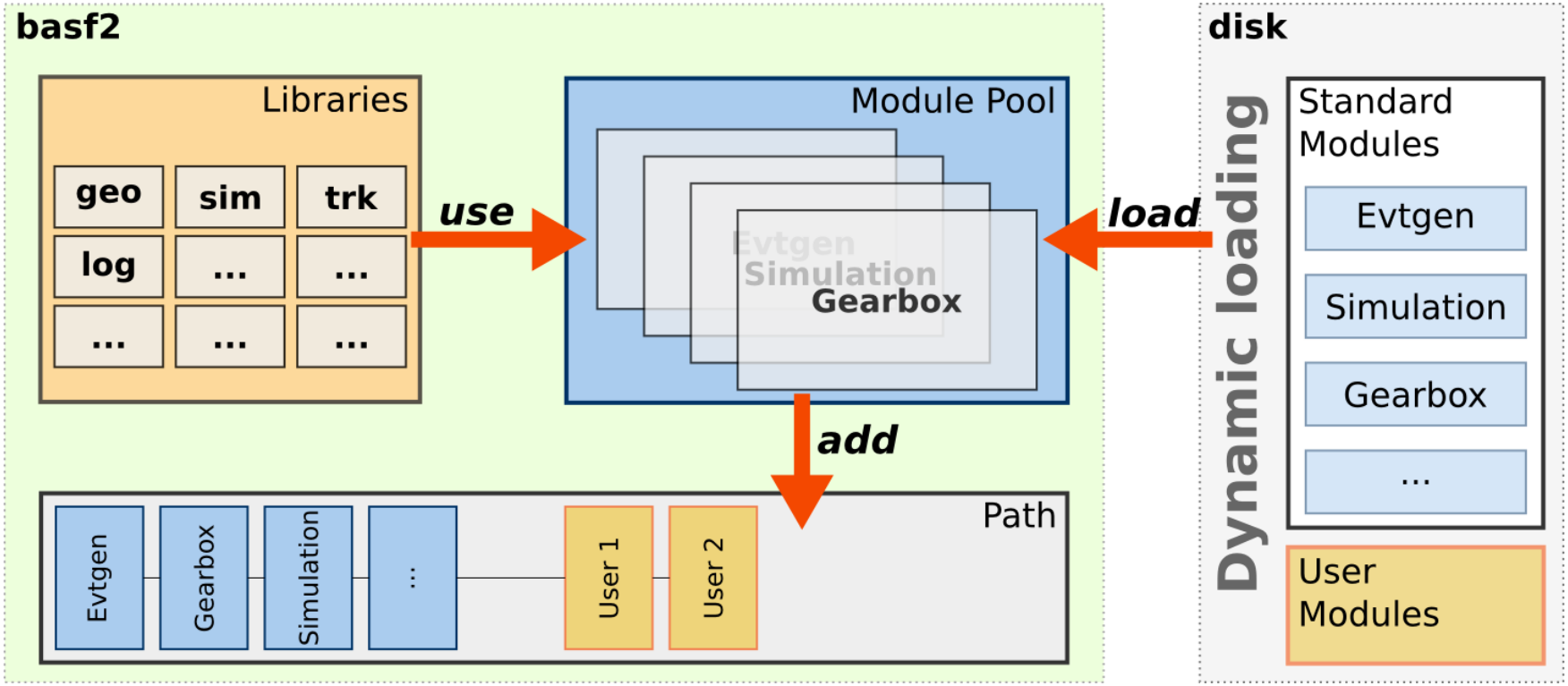
Belle II Collaboration



23 countries, 99 institutes, 672 collaborators

Backup Slides

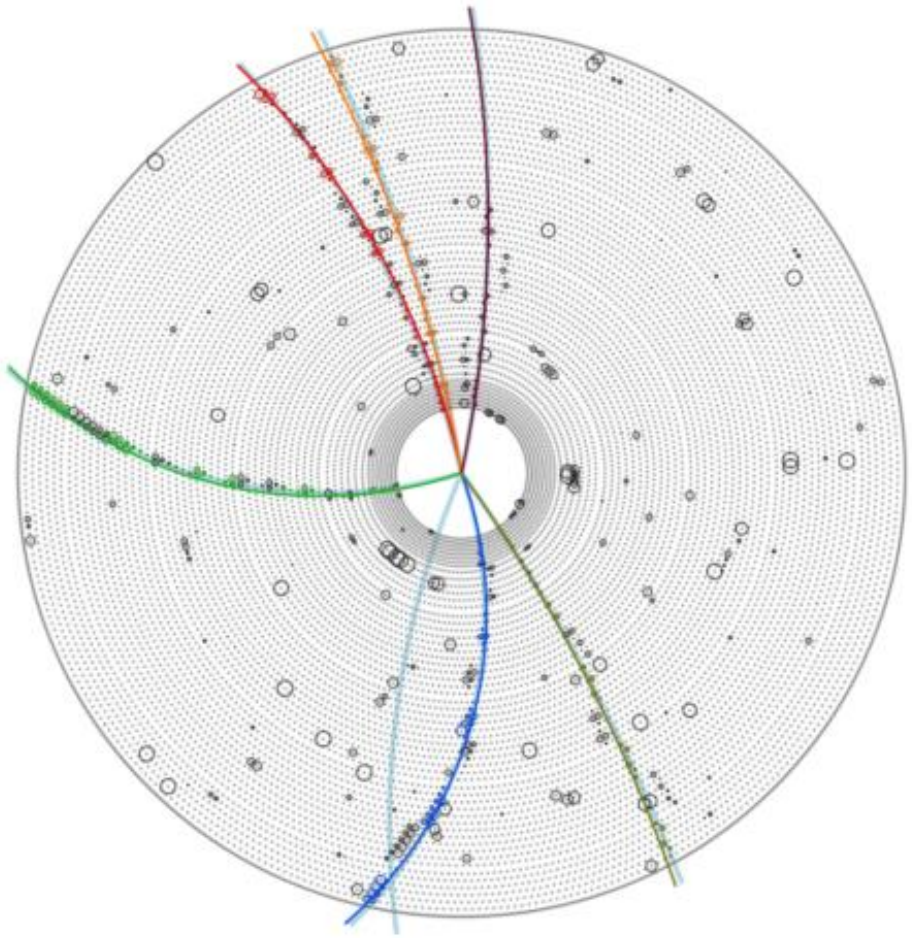
Libraries vs Modules



- 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

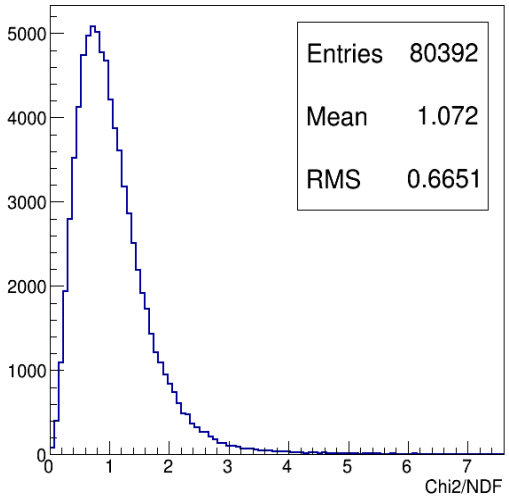
Results of Legendre Finding

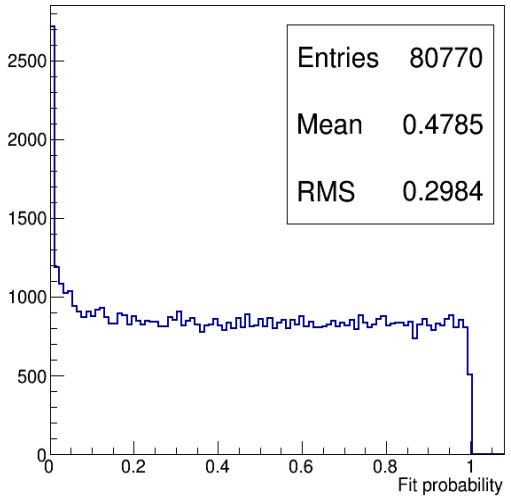
- Simulated event: $B^- \to D^0(\to K^- \pi^+)\, \pi^- +$ beam background



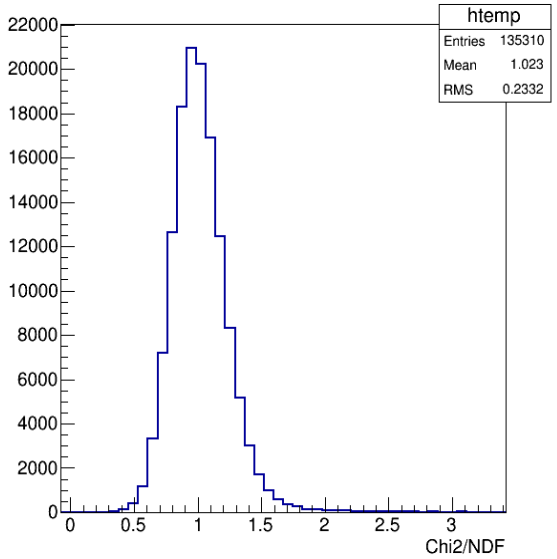
GBL Fit Results

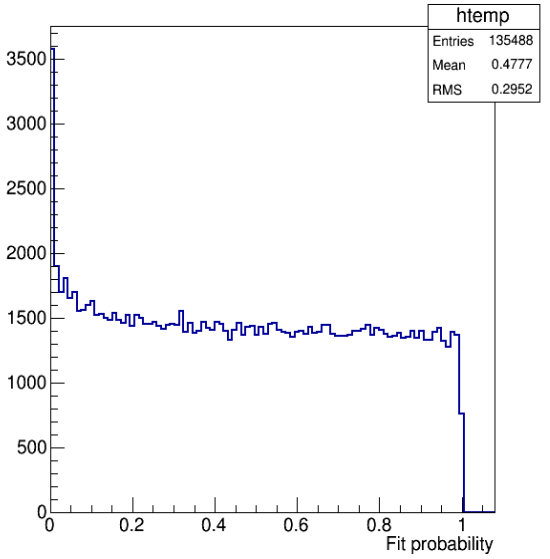
- VXD only



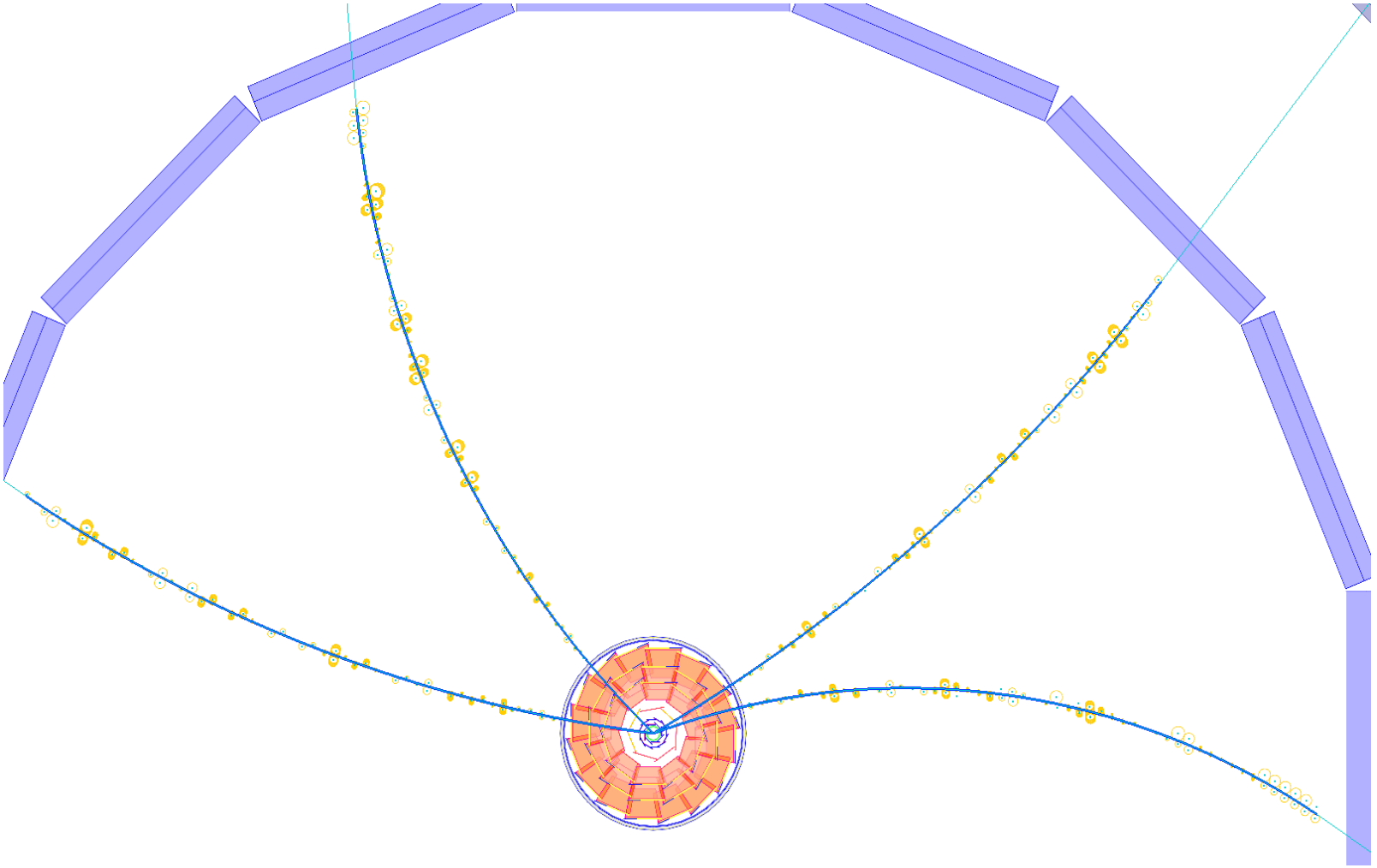


- VXD and CDC





Event Display for Track Fitting with GBL



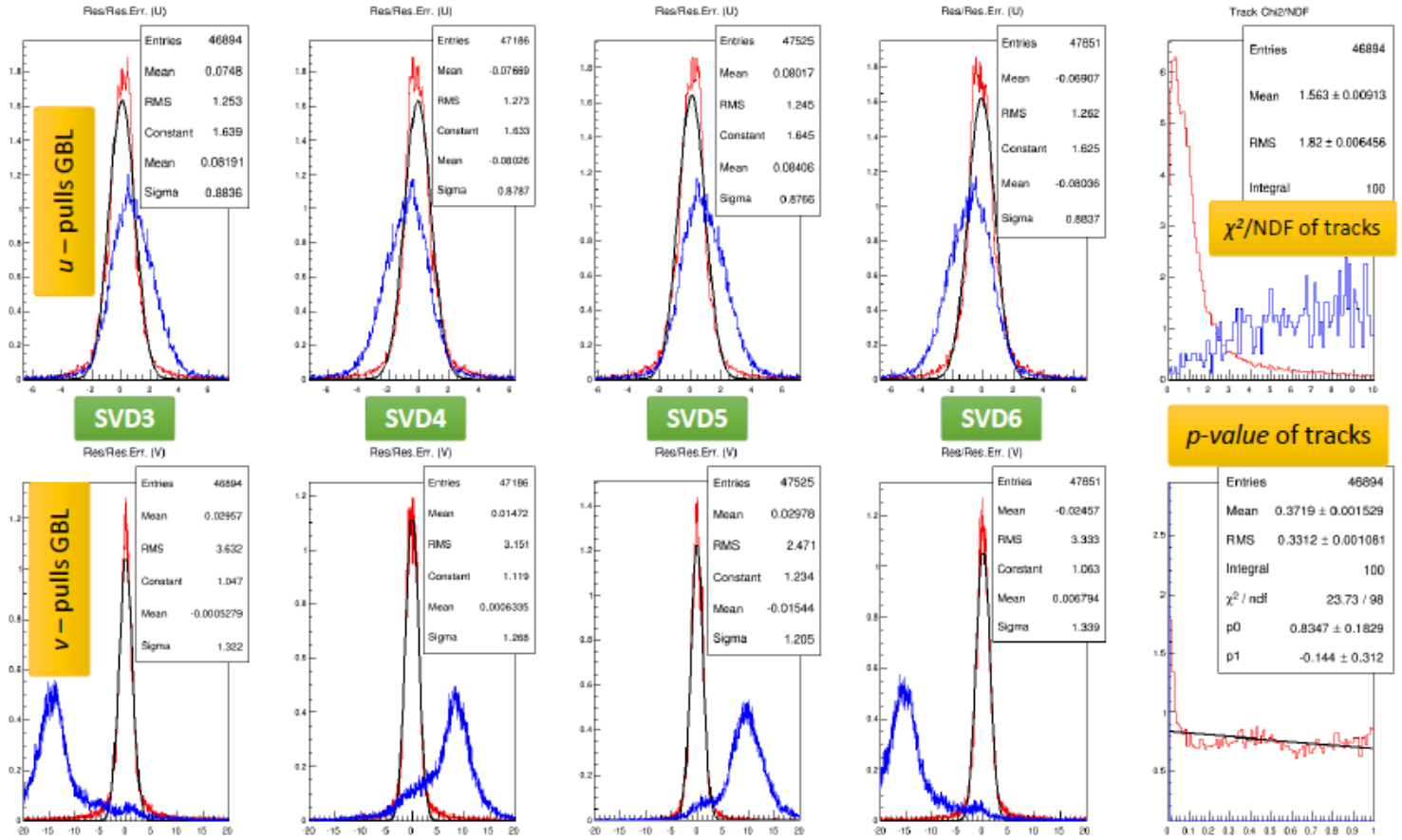
Alignment Results for the DESY Beam Test

RUN 507 | Full tracks with 4 x 2 x 1D measurements
B=**1T** E=**4GeV**
Combined alignment data: **500**(4GeV)+**507**+**508**(5GeV)
SVD3 fixed, SVD6 fixed shifts.
Shifts and in-plane rotations only.

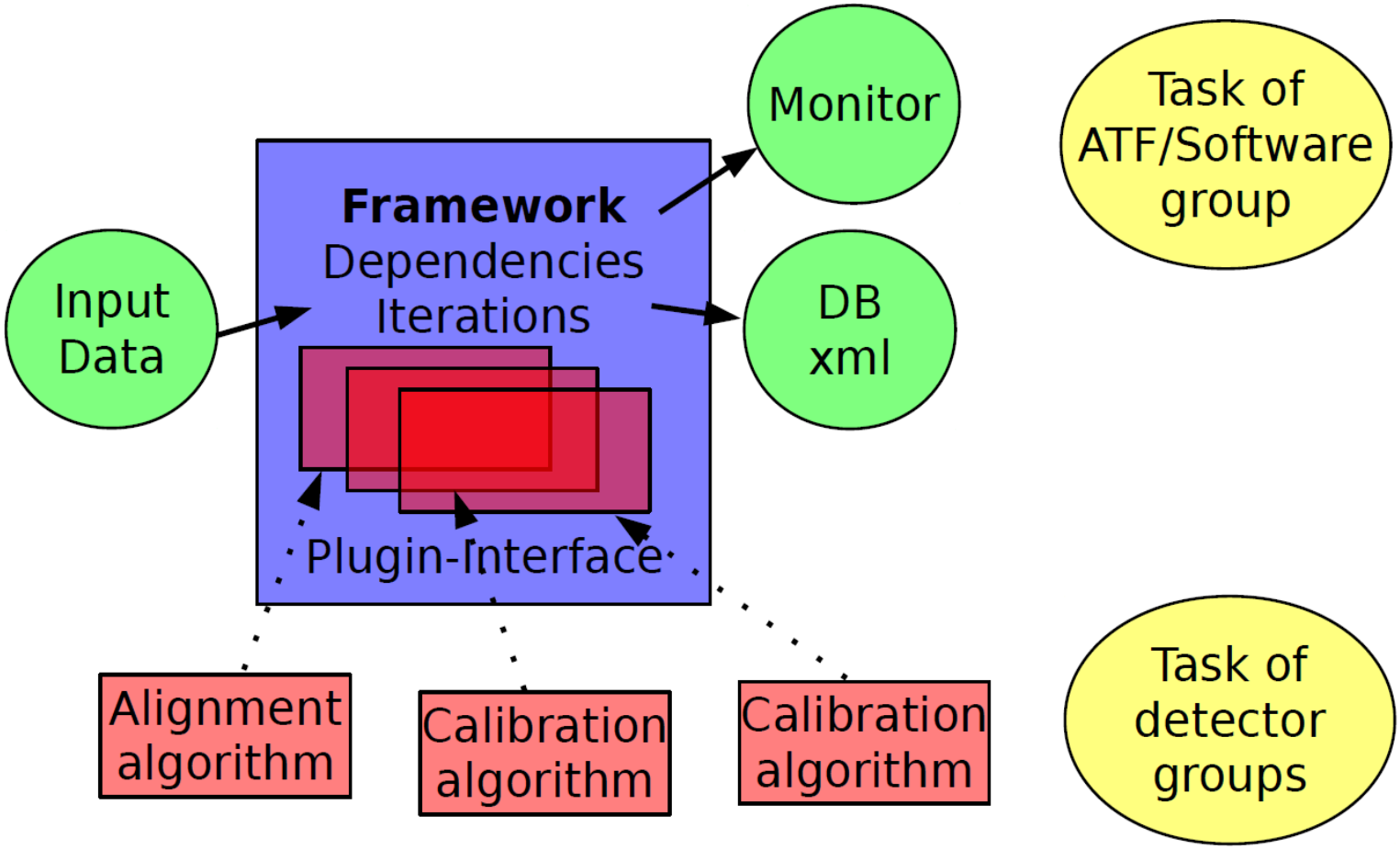
DESY TB Alignment PRELIMINARY

Before and *after* *Millepede II alignment*

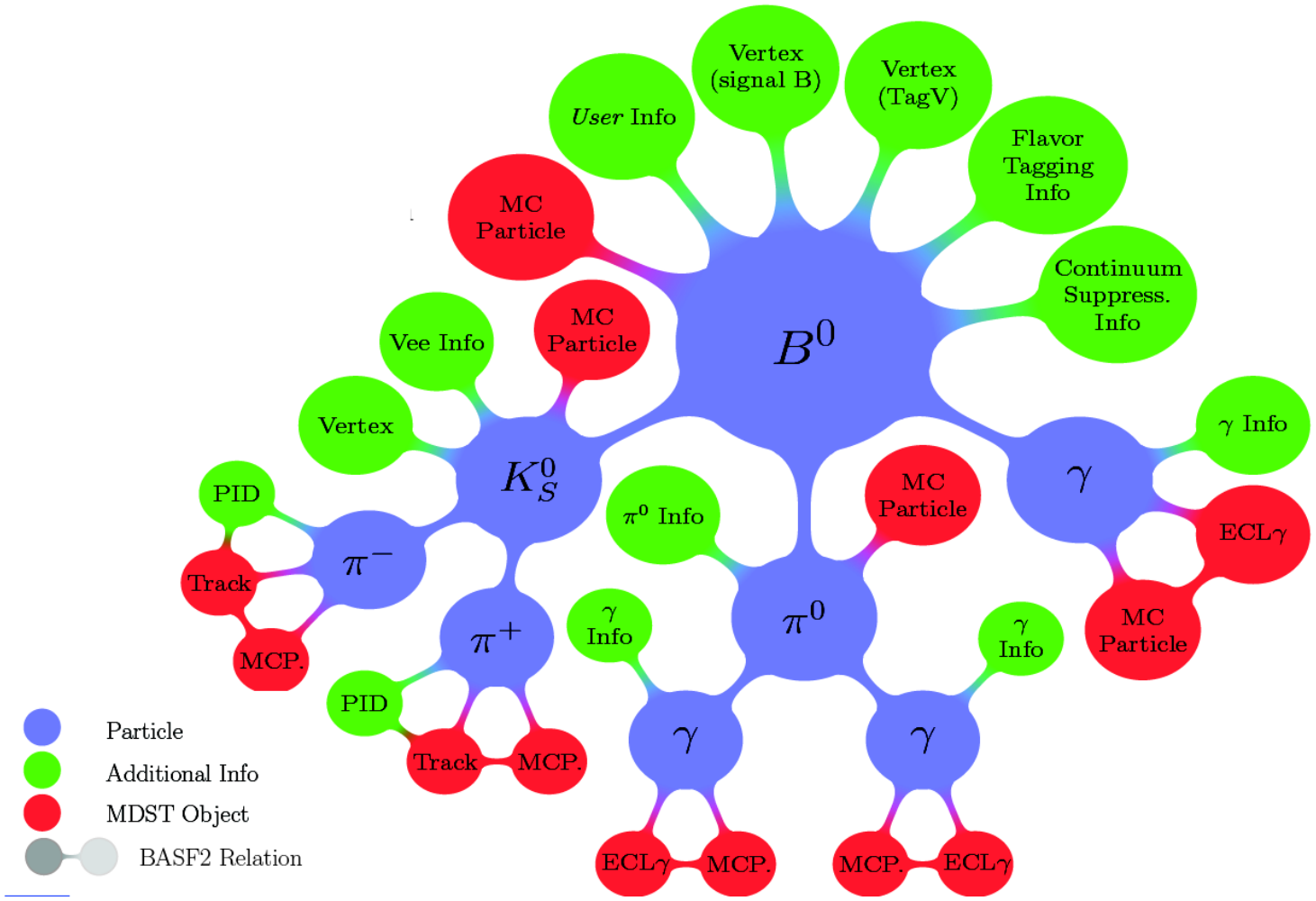
Normalized histograms (vertical axis in %) with results of **GBL** fit. **Pulls**: GBL residual / GBL res. error. Bending plane in *v*



Calibration Framework Scheme

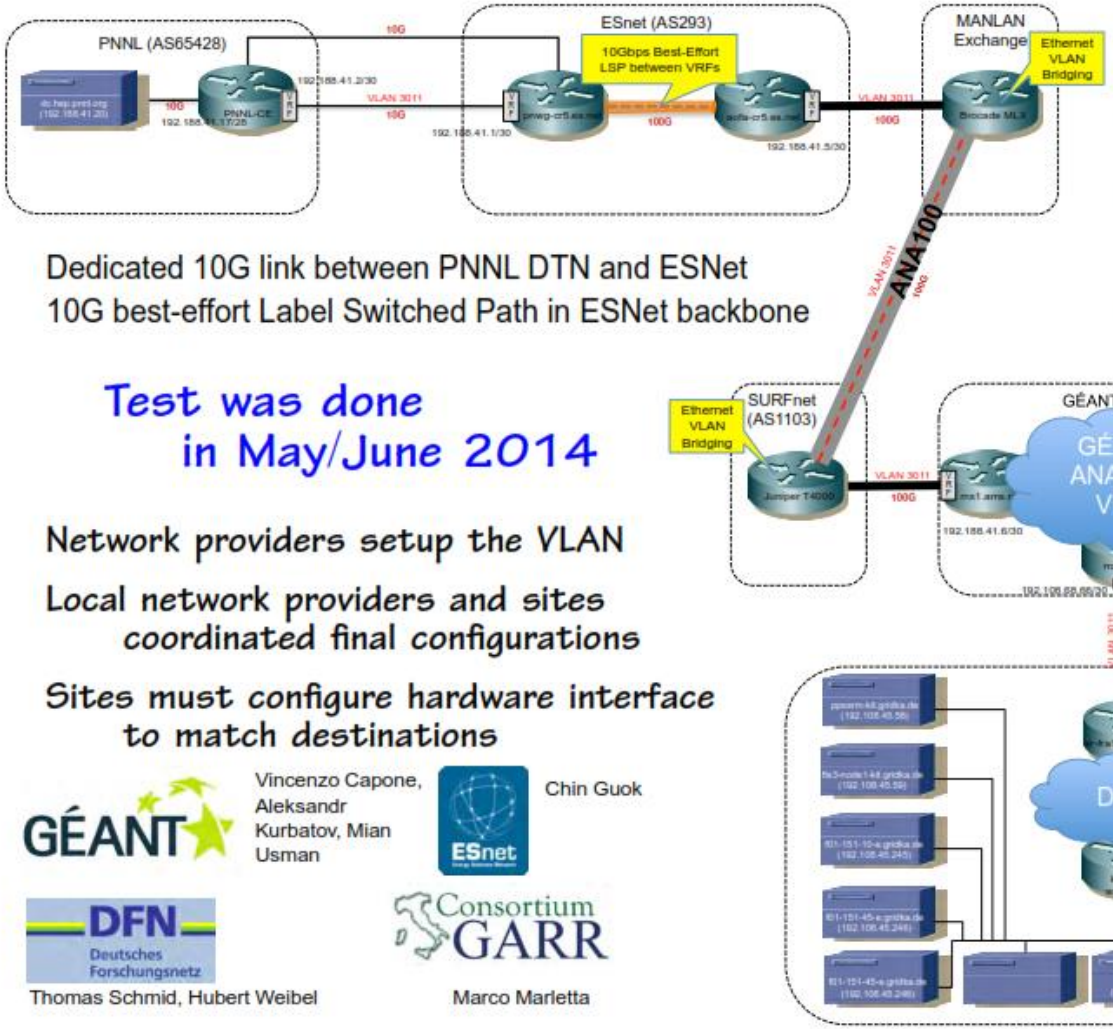


Ntuple Tools



Trans-Atlantic Data Challenge

US side



Dedicated 10G link between PNNL DTN and ESNet
10G best-effort Label Switched Path in ESNet backbone

Test was done in May/June 2014

Network providers setup the VLAN

Local network providers and sites coordinated final configurations

Sites must configure hardware interface to match destinations

- "traceroute" was used to confirm the routing to each DTN
- "iperf" was used to do initial network transfer rate test
- "gridftp" and/or "srm-copy" was used to test site
- FTS3 server at GridKa was used to schedule data transfers

EU side

GÉANT — Vincenzo Capone, Aleksandr Kurbatov, Mian Usman

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Belle II Computing at DESY

- *BELLE2 (VO 'belle')* is well supported at DESY commonGrid infrastructure
- At DESY the *federation* of Grid computing resources and its *opportunistic* usage models allows to very efficiently distribute free resources
- BELLE2's 4th MC campaign strongly benefited from new resouces which were procured to meet the pledges in 2015 and old resources which were kept running as well as from partially little job submission by ATLAS and CMS
- In 2014 BELLE2 used 11% of the DESY Grid computing resources (ATLAS: 34%, BELLE2: 11%, CMS: 48%, ILC: 6%)
- DESY will guarantee half of the requested resouces of Germany in 2015 (8 kHS06, 240TB)
- The *National Analysis Facility* (NAF) complements the Grid for interactive data analysis and supports BELLE2; more users are welcome!