CMS software

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Outline

- Threading in CMSSW
- Git / GitHub / Integration infrastructure
- Simulation and Geant4
- Conditions

Threaded CMSSW framework design

- Run multiple data taking transitions in parallel
- Run multiple modules concurrently within one event,
  - Change to user code: Needed more information about module dependencies: Declare what data products a module will consume in addition to what it will produce
- Run multiple tasks within a single module concurrently

Use TBB for all of these by breaking down work into "tasks"

Framework implementation: Thread safety requirements

Data Products

- Information passed from module to module
- Only const access to data products is provided
- **const member functions must be thread safe** (Matches C++11 thread-safety guarantee for containers)

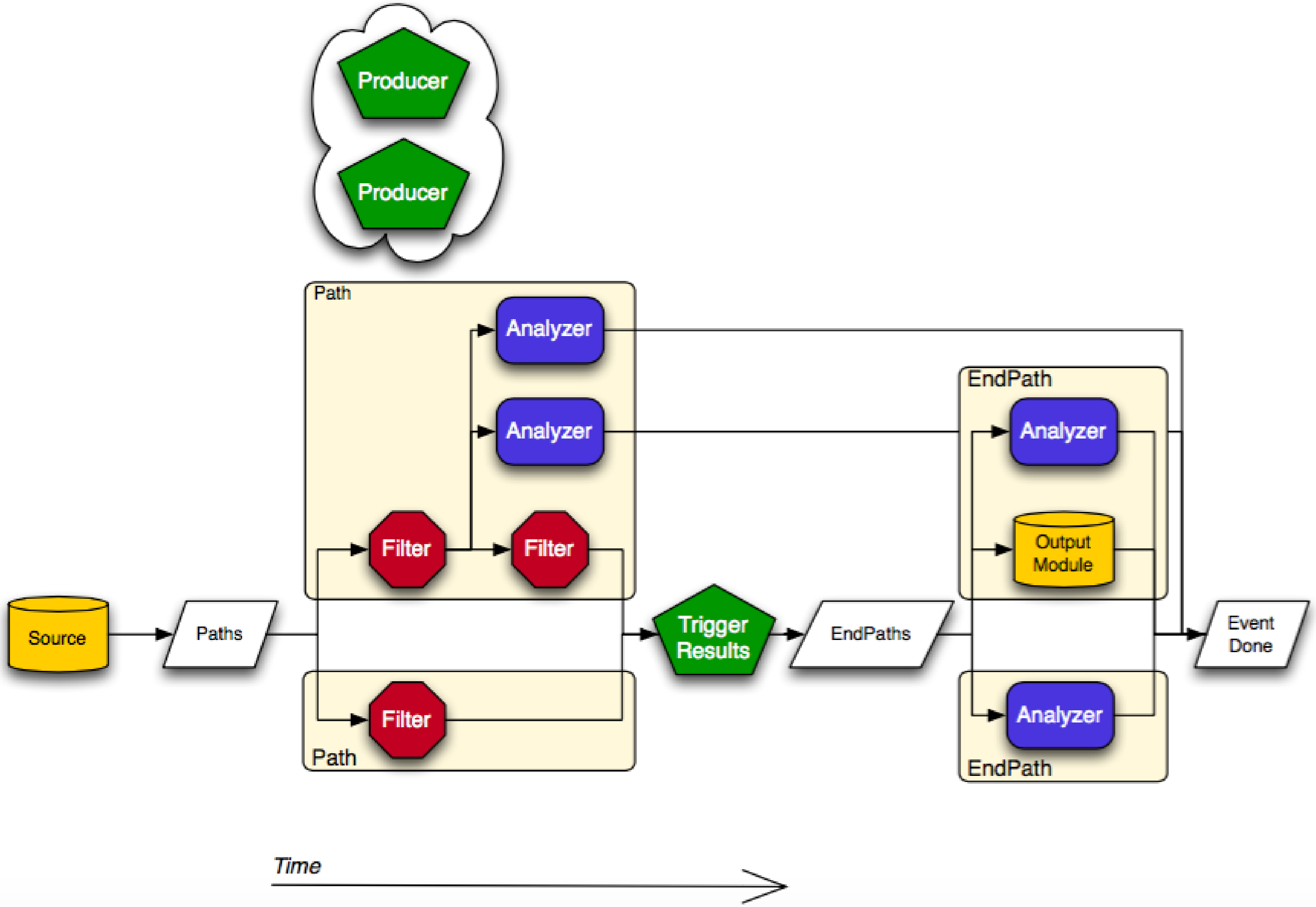
EventSetup modules (primarily conditions information: IOV driven)

- EventSetup using one mutex
- If an EventSetup modules needs to run, the lock is taken. However, accessing cached data does not require a lock

Producer, Analyzer, Filter modules

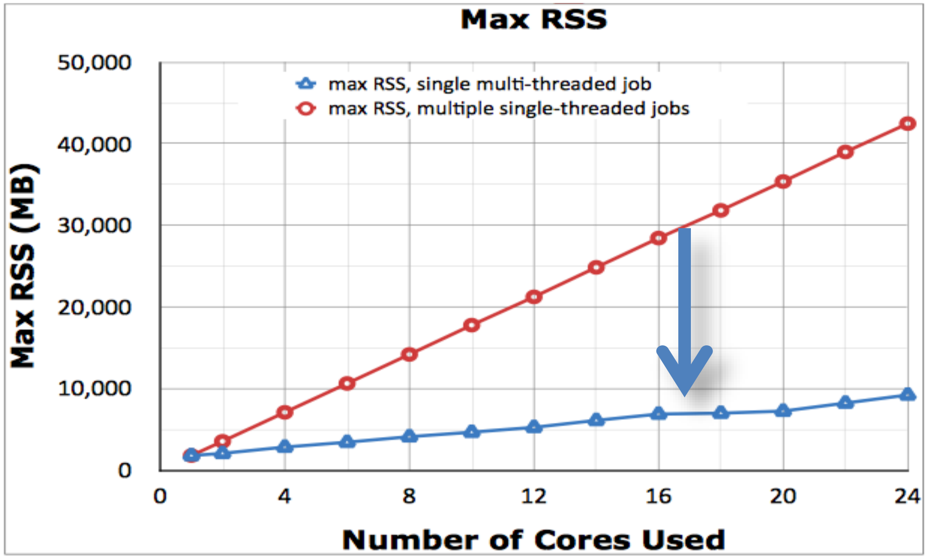
- Majority of user written code
- Module base class options define thread safety requirements
  1. **Legacy**
  2. **Stream:** One copy of module per stream (thread)
  3. **Global:** Reentrant, sees all events
  4. **One:** Shared by all streams (not thread safe)

Threaded CMSSW Framework concept



Multithreaded status

Example RSS savings from threading in CMS (reconstruction)



- Status of our main workflows in production
  - 2015: Tier-0, HLT, data reconstruction run multi-threaded
  - 2016: All major workflows are able to run efficiently in multithreaded mode. Still working through deployment details
- Framework development goals for 2017
  - Parallel running of modules within an event
  - Parallel running of events in multiple lumi sections

Some lessons learned

- Approach based on different flavors of algorithms (legacy, stream, one…) has eased the transition to production
  - Even simple interface changes prove to take a long time to complete (in CMS at least).
  - Debugging still largely a core SW group task: Fortunately we have not experienced major or extremely rare problems
  - Optimization also largely a core SW group task, but CMS tools for identifying bottlenecks are improving
    - Identify modules responsible for stalls
    - Helgrind
    - Static analysis

Threading optimization: We use VTune very successfully

GIT TRANSITION AND WORKFLOWS

CVS → GIT transition for CMSSW

- Transition motivated by the end of CVS repository hosting support at CERN [Transition completed summer of 2013]

- After an evaluation of different options (SVN, CERN hosted Git), we migrated the CMSSW code repository from CVS to **GitHub**

CVS → Git transition

- Repository structure: We stayed with one repository for all of CMSSW
  - We did not see a way to split the repository in a way that would not allow most requests to be against just one repository
  - Given 1100+ packages, we defined a mapping between code chunk ("packages") and software conveners responsible
- Repository structure
  - One branch per release cycle plus branches as needed for operational bug fix release builds
  - Handful of people that can integrate code
- We moved beyond nearly all of the CVS specific utilities we had developed during Run 1 (not initially, but over time)
  - Using the gitHub API to drive request, testing and integration procedure

CVS → Git transition

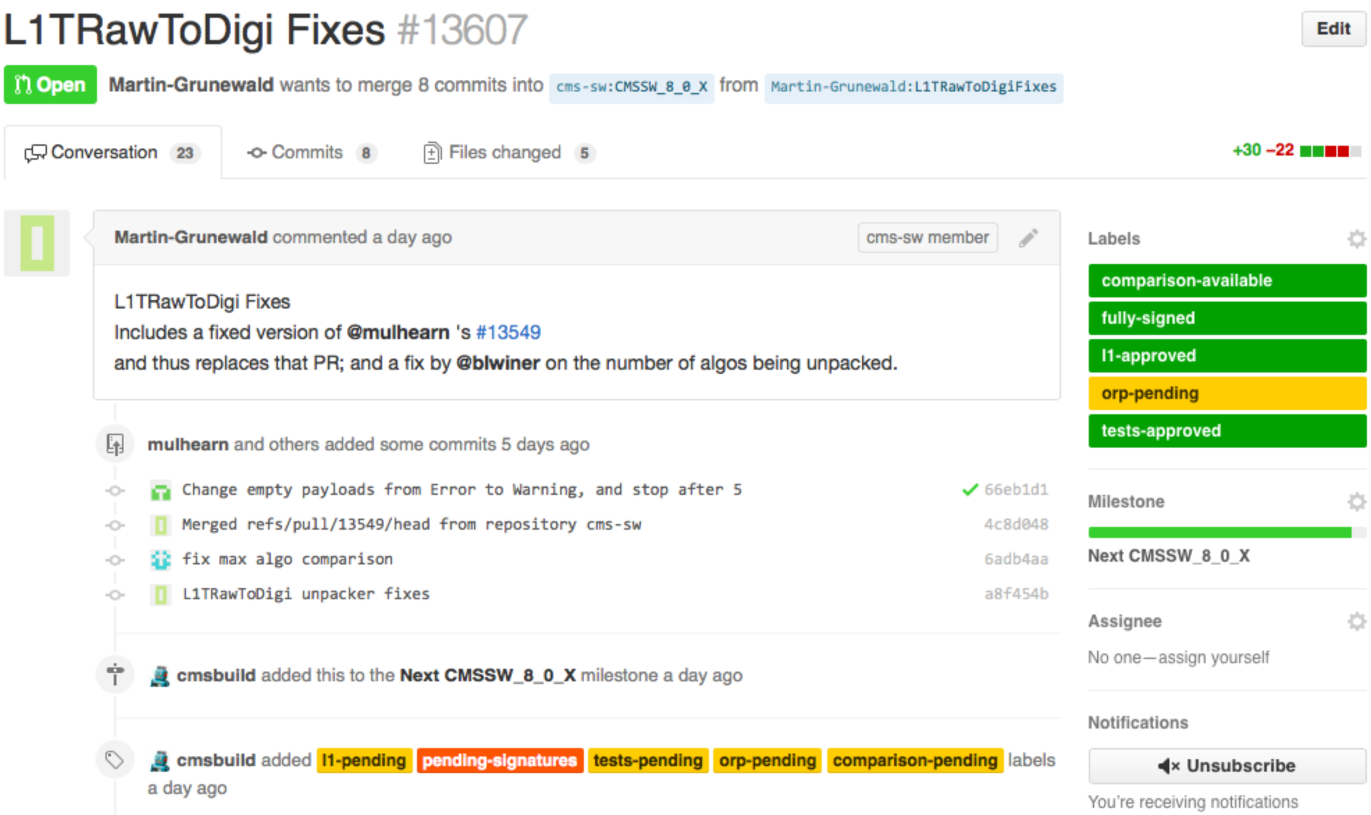
- Development history:
  - We kept old official release tags from CVS but not the private tags that we allowed in CVS packages
  - Full file history is preserved (even if not trivial to access)

- Data files: We moved all sizeable data files into separate repositories to keep the CMSSW repository size manageable.

- Caching our repository locally helps considerably

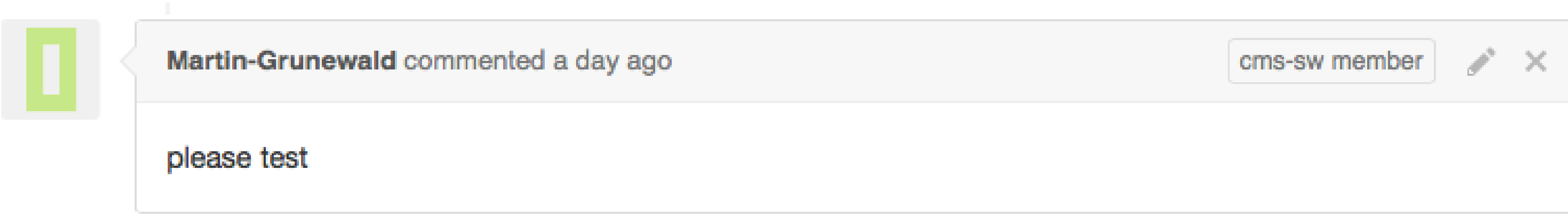
Code request lifecycle (example)

- User makes a pull request to the cmssw github repository

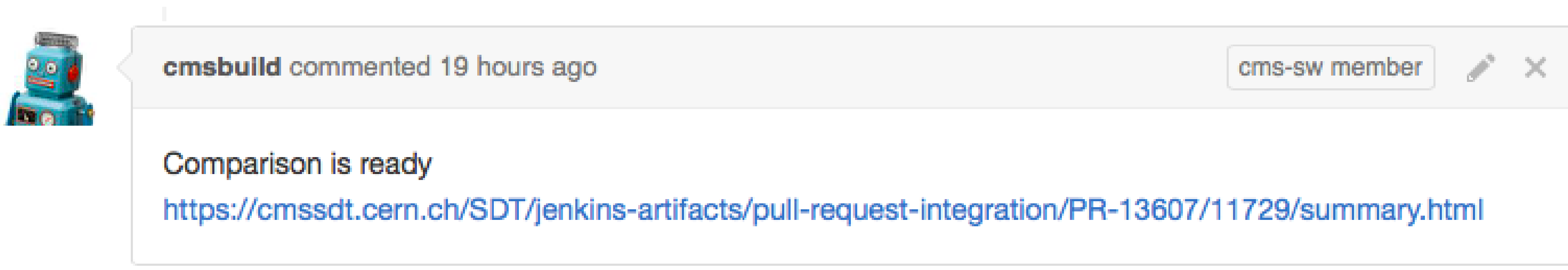


Code request lifecycle (example)

- Standard tests are requested (by “known” users)

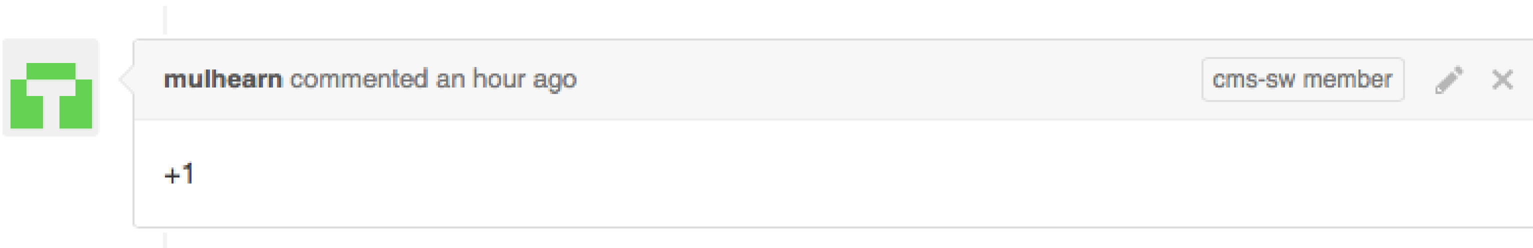


- Comparisons are returned for evaluation by category managers (these are behind the CERN SSO)

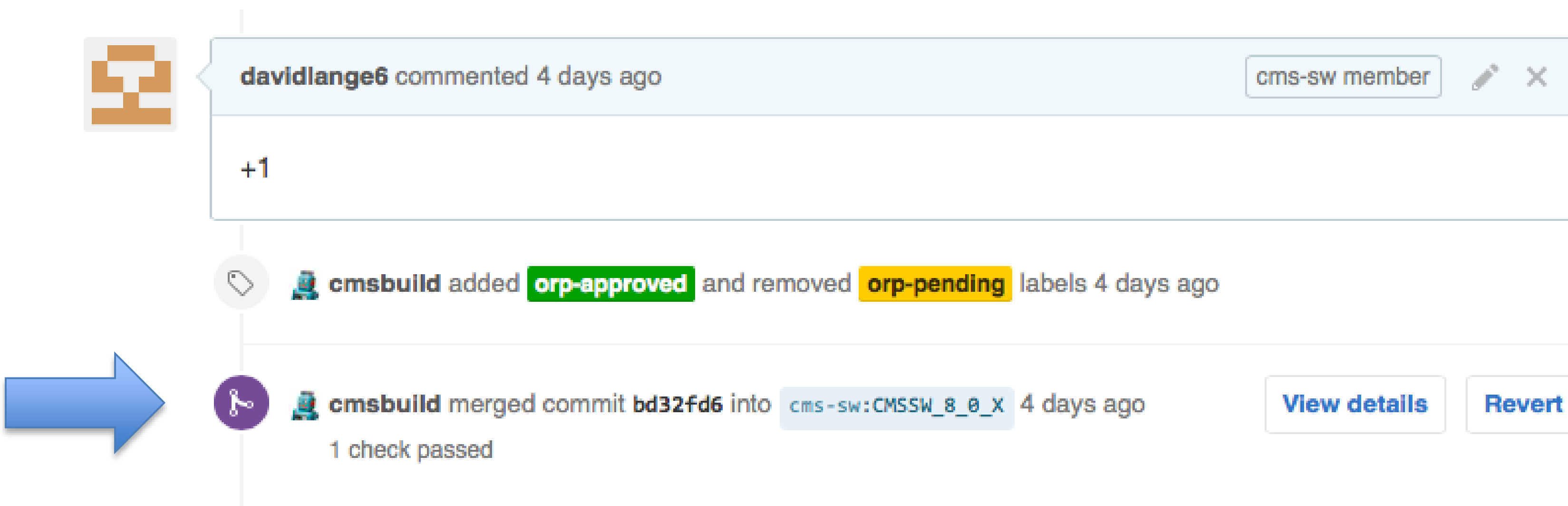


Code request lifecycle (example)

Request is approved by category manager



Request is approved by release manager and integrated into CMSSW



Successes / issues

- Git has proven much better for managing complex change requests and has reduced the interference between concurrent requests considerably
- GitHub has proven very reliable (much higher up time percentage than the CERN CVS service had for CMS)
- Despite changing the vision of our workflow after the initial migration, we have an efficient and easy to maintain system for integration and release builds
- We left some users behind (as expected)
- Information private to CMS needs another solution rather than GitHub

GitHub+Jenkins workflow for releases

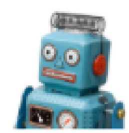
- **Jenkins**
  - -JAVA based continuous integration system
- **Git and Github**

cms-bot

- https://github.com/cms-sw/cms-bot
- Python and shell scripts to **automate our workflows.**
- Self-sentient and very friendly, designed to comply with the 3 laws of robotics.

New Github Issue:

Build <Release Name>



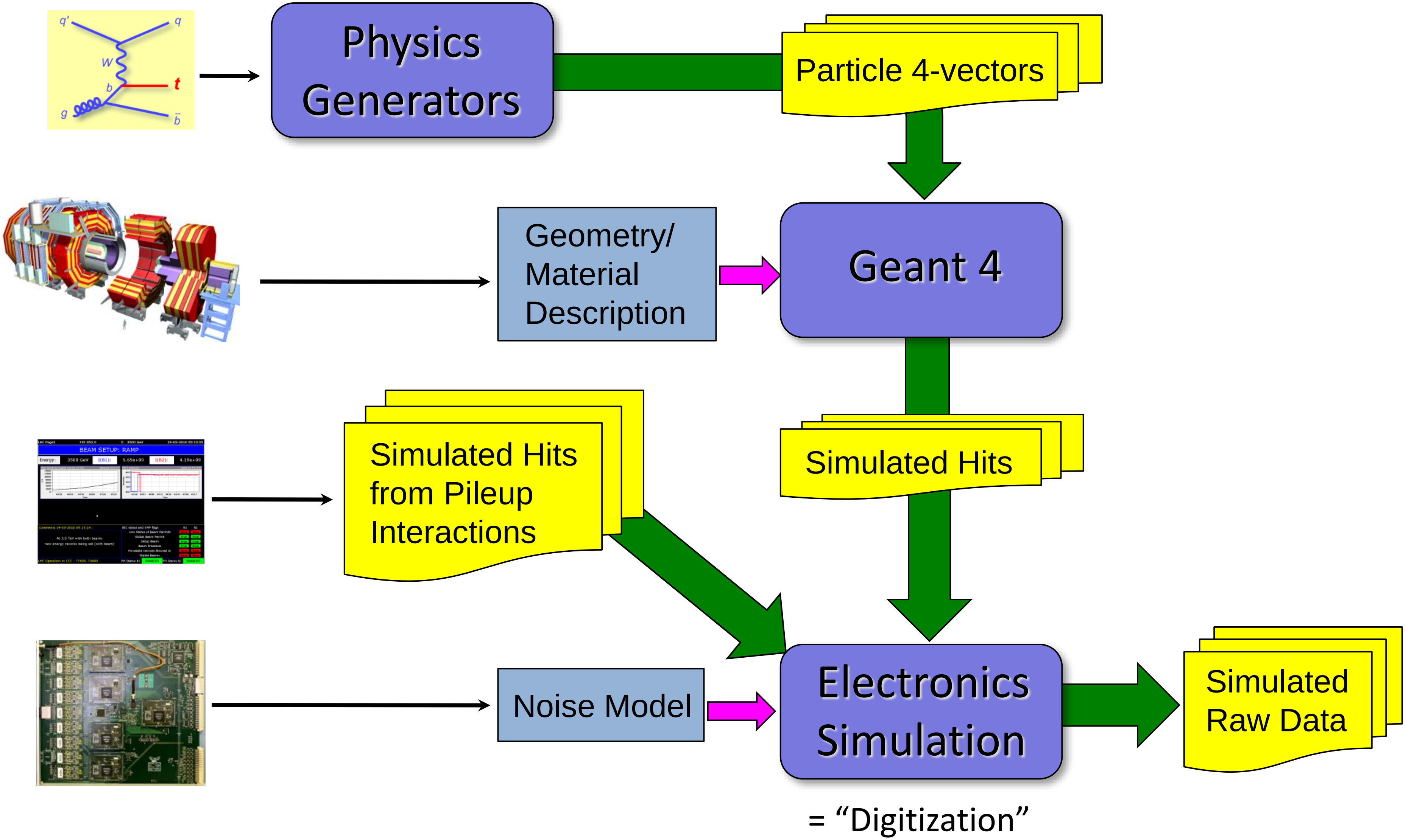
Release is built automatically.

Release / integration building system

- In production for ~2 years (100-200 release builds). System supports ~7 active release cycles
  - Build, testing, upload, install steps are each triggered by "+1" from release manager
  - Same infrastructure sits **behind integration build** system (2x per day per release per architecture) and **pull request** testing
    - Means reduced system complexity and IBs provide a testing facility of release build software
    - Straightforward to integrate tests into each build. Tests run vary by type of build
    - Recently expanded to include testing of "external" changes (eg, Pythia8, Geant4 version updates)

SIMULATION

Simulation approach including digitization and pileup simulation



Geant4 status in CMS

- **Production version of Geant4 for 2015-2016**
  - Geant4 version10.0+patches built in sequential mode
  - Default physics List QGSP_FTFP_BERT_EML (Best agreement with CMS test beam data in studies years ago)
  - CMS produced ~9 billion events in 2015

- For 2016: Most CMS simulation samples re-use the detector simulation samples we generated in 2015
  - Typical approach for us when no detector changes are made.

- CMS installs a new pixel detector in 2017, so we will try to update the detector simulation software (Pythia8 tunes, G4, etc)

Geant4 status in CMS – development for 2017

- **Current development version of Geant4 in CMS is Geant4 10.2+patches**
  - Multi-threaded Geant4 is fully integrated with CMS multi-threaded framework
  - Updated physics lists given test beam results currently under evaluation

- Preliminarily: 10.2 shows worse agreement with test beam data. This is under investigation together with the G4 hadronic team
  - Changes to our physics list and patches to 10.2 now under evaluation

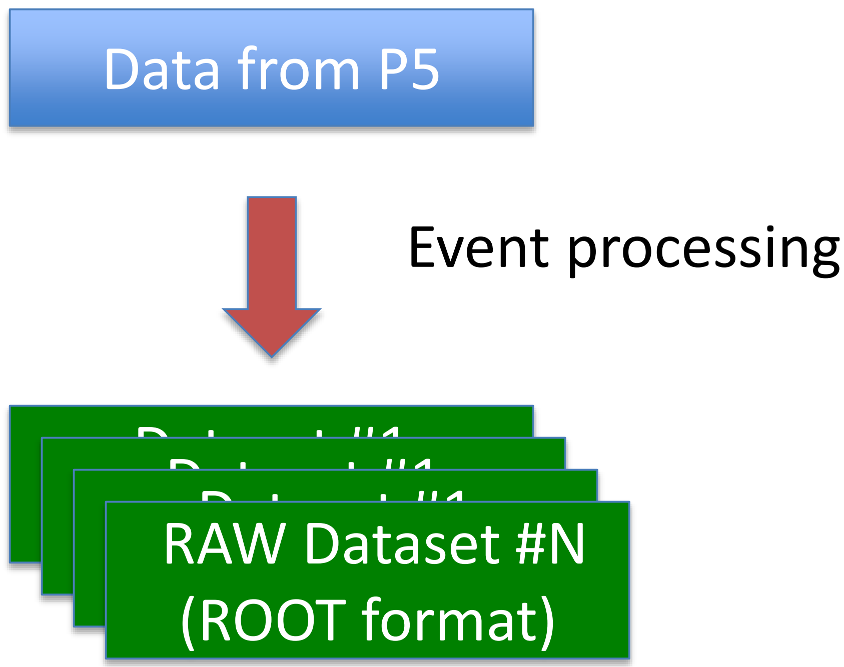
TIER-0 / RECONSTRUCTION CONFIGURATION+WORKFLOWS

Tier-0 workflows and configuration

- Primary evolution during Run 2
  - Multithreaded (typically 4 threads)
  - Added “MiniAOD” output
    - Meant to be small and easily reproducible starting from Run 1 analysis data tier (“AOD”).
  - Multithreading allowed us to add “prompt skims” for physics and detector studies as part of our Tier-0 workflow
    - Previously done on Tier-1 outside of Tier-0 infrastructure

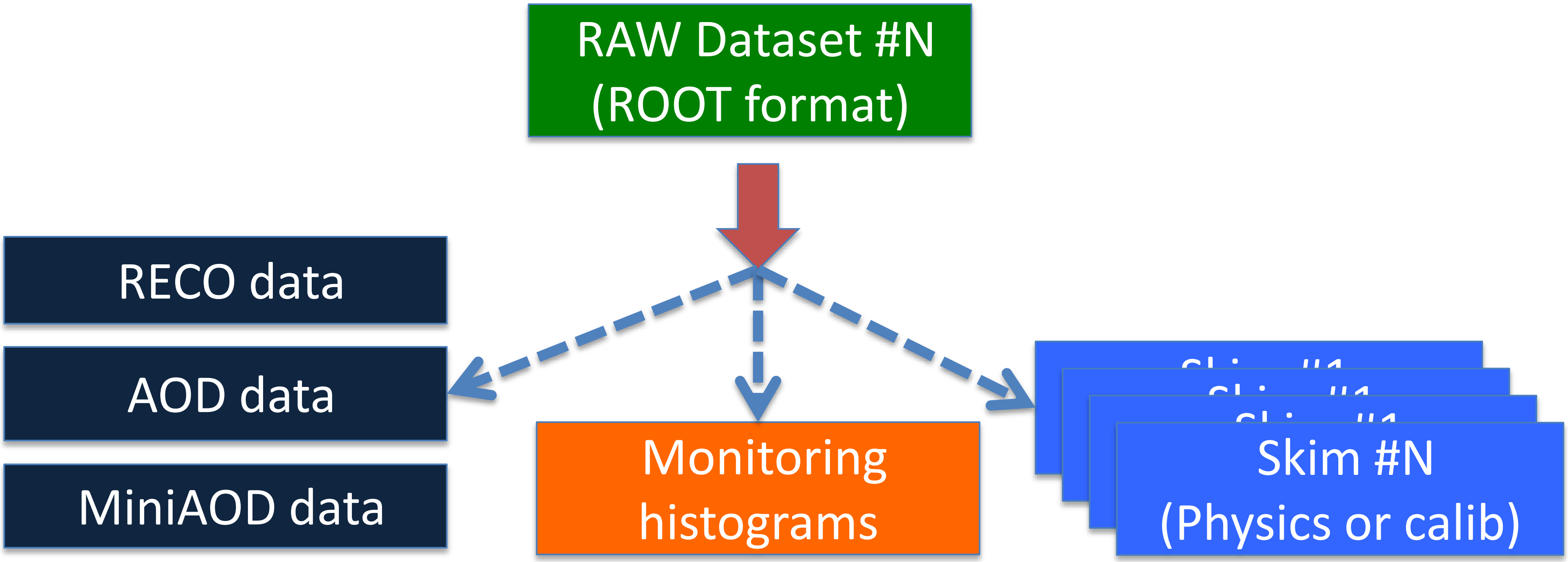
Tier-0 workflows: Repacking step

- Split events into dataset using HLT decision bits and convert to archival RAW data format (ROOT based)

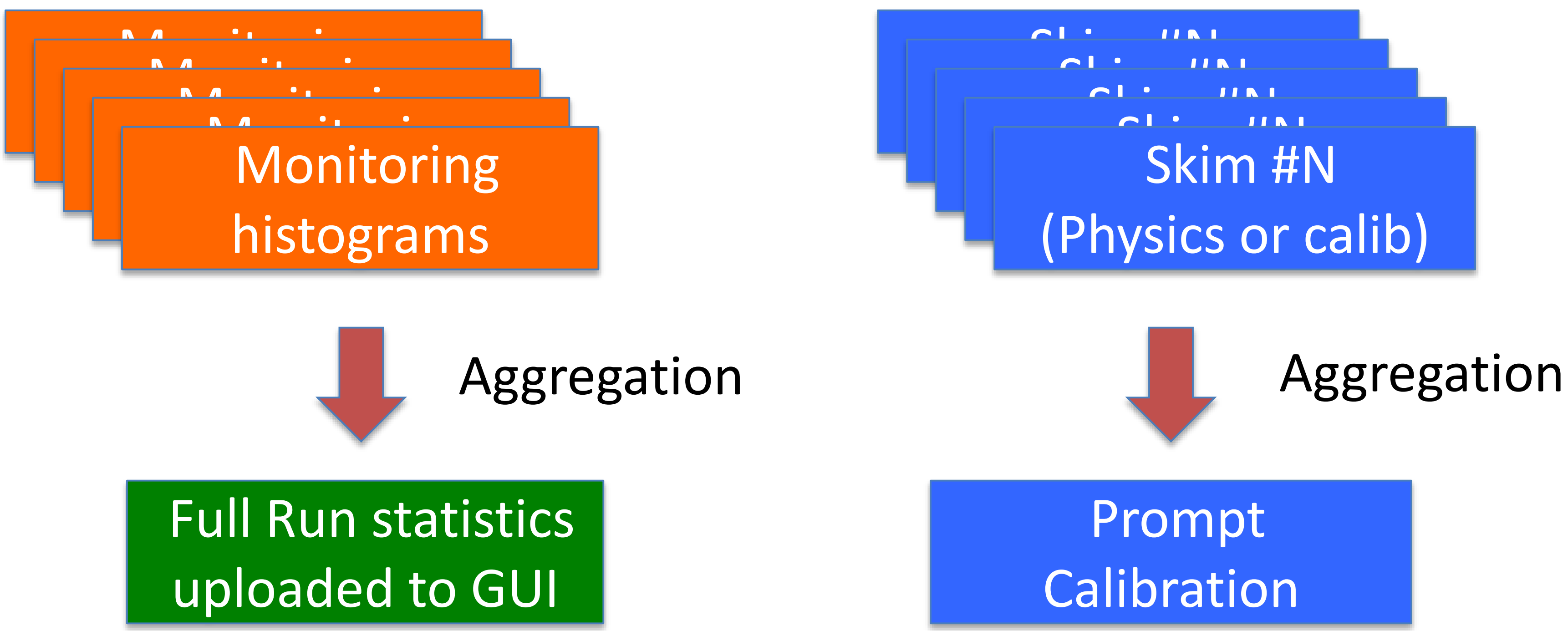


Tier-0 workflows: Reconstruction step

- Perform all event processing in single step
- Today we have only a few skims. We have ideas for how to better isolate individual skim configurations from each other (and rest of application) in case their complexity grows



Tier-0 workflows: Merging and Harvesting

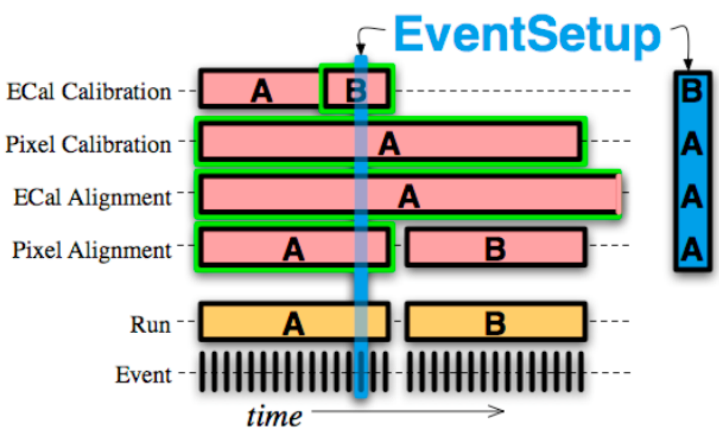


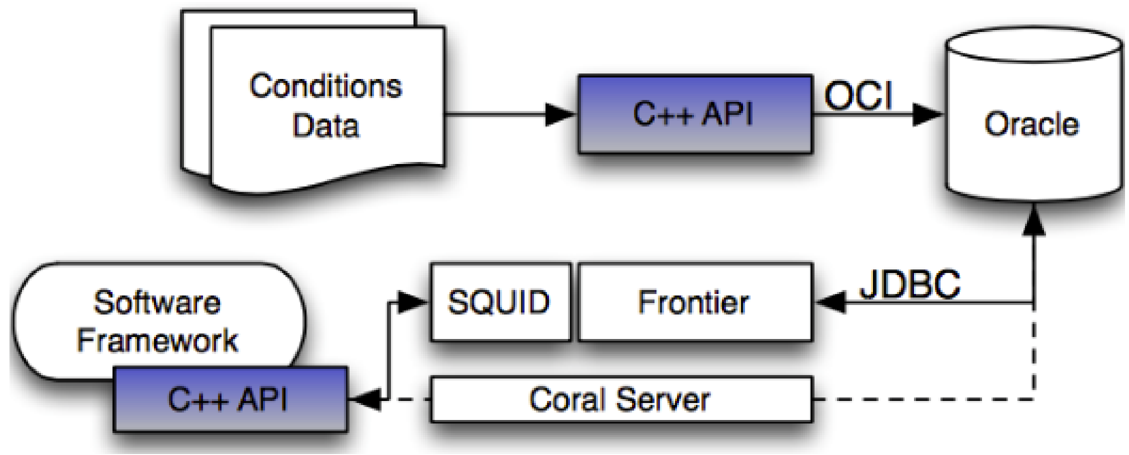
CONDITIONS

Alignment and Calibration (non-event) data: Run 2 Conditions system in CMS

- Conditions infrastructure rebuilt based on lessons learned during Run 1
  - Reduced complexity of data representation: Multiple tables per conditions object became 1 blob
  - “Global tags” handled in more natural way
- CMS conditions vary with run/lumi (mostly) or time (a few)
  - Multithreaded framework relies on lumi boundaries as the synchronization point

Alignment and Calibration (non-event) data: Run 2 Conditions system in CMS

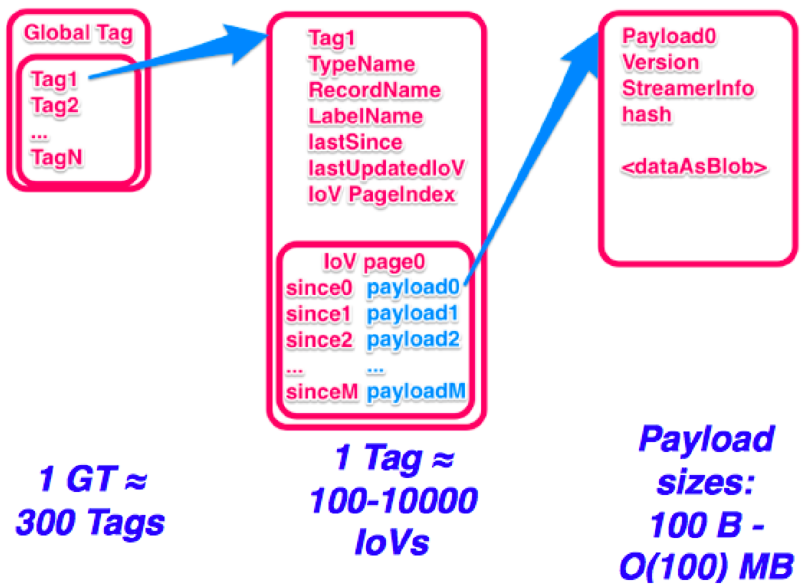





```
ESHandle<TrackerGeometry> geomPtr;
eventSetup.get<TrackerAlignmentRecord>()
      .get( geomPtr );
```

Conditions model

- **Conditions data**: Serialized and stored as **blob** in database
  - We chose to use boost serialization package
- **Interval of validity (IOV):**
  - Defined by “since” (time, lumi) with an open IOV
  - We do not have a use case for very fine grained IOVs. Would require an interface to retrieve “until” (time, lumi) for framework syncronization
- **Global tag**: Defined by a consistent set of tags



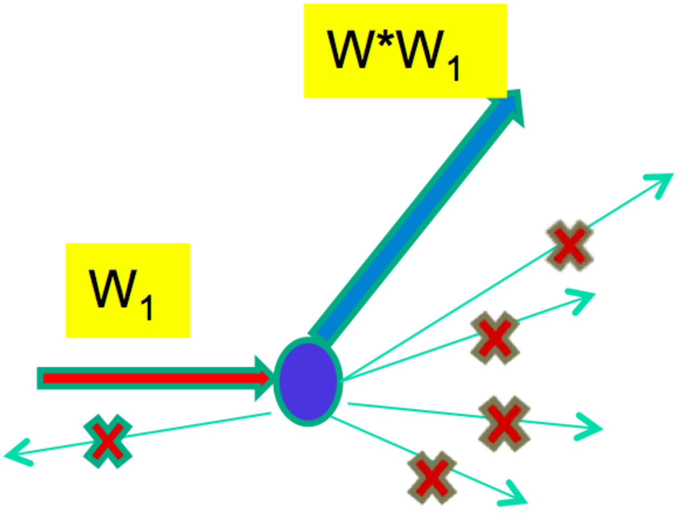
Assessment after one year of operations

- Load on DBAs and experts-on-call is dramatically reduced
- Oracle satisfies our requirement for a highly reliable database service
  - With blob and our IOV schema, DB queries are simple and easy to maintain
  - Now able to investigate other solutions for Oracle functionality for Run 3.
- Schema evolution:
  - So far users have not faced issues with the lack of schema evolution support in the serialization
  - There is however a strong coupling to boost version (lack of "forward" compatibility. Needs to be solved in longer term but not a risk to data taking operations

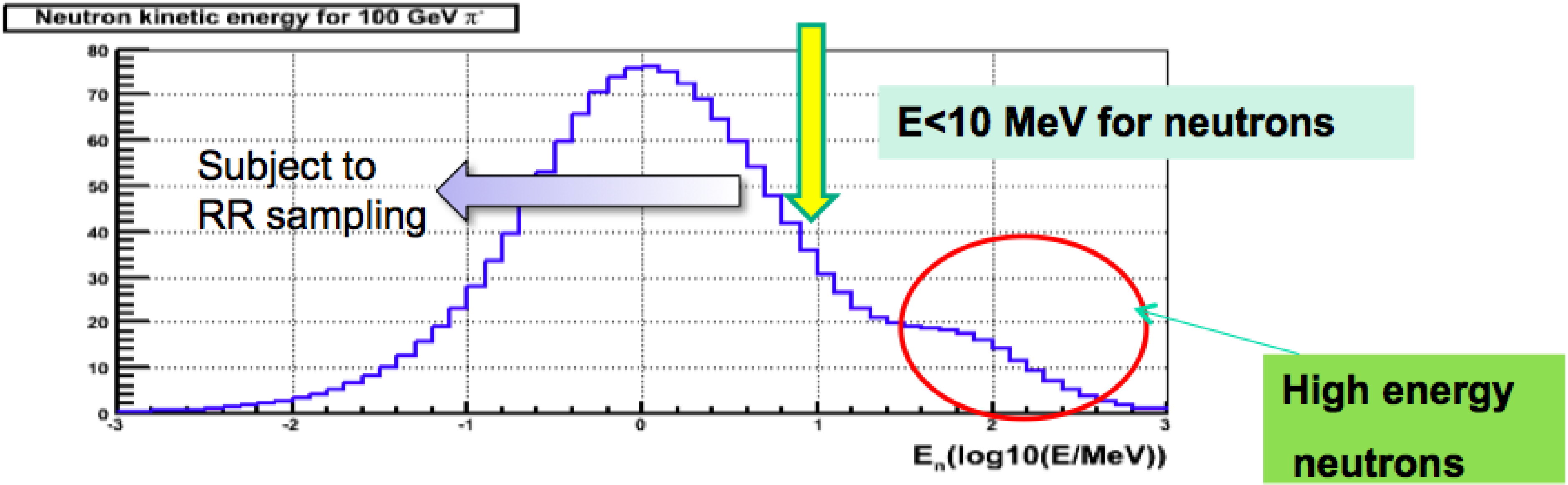
Questions?

Russian Roulette: Sampling of low-energy particles in Geant4

- Method from neutron shielding calculations: Track only a small fraction of low-energy particles through the detector with no noticeable change in simulation results
  - We found that it was necessarily to have sampling factors and thresholds that depend on both detector region and particle type.
- Two parameters:
  - RR factor (1/W): Fraction of particles to keep
  - Upper energy limit (E_{RR})
- Hits from Particles below E_{RR} that are tracked are given a weight W.



Russian Roulette now used by default after long tuning and validation process



- RR factor of W=10 for neutrons and gammas found to give between 25% and 40% performance improvement with no observable effect on physics output
  - Energy and shower shape response in the high-resolution ECAL barrel detector were the most sensitive to RR parameter tuning