US CMS Physics Analysis

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DOE/NSF Baseline Review of US CMS Software and Computing

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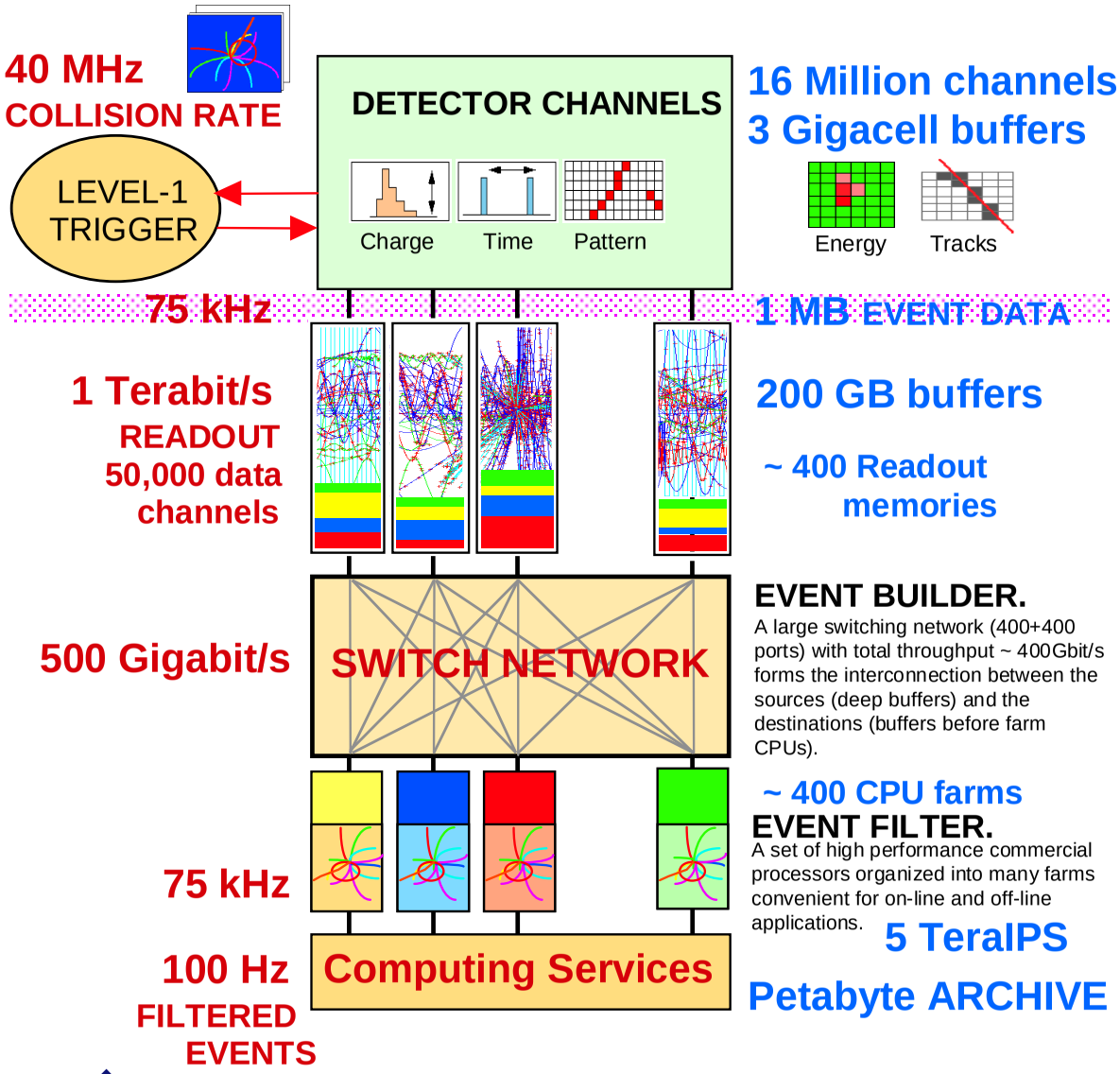
A Great Opportunity

- The most exciting new accelerator since…
  - EW Symmetry Breaking, Origin of Mass,
  - First Scalars
  - SUSY
  - Big step in Energy and Luminosity $\Rightarrow$ Much more
- US has full access to the data.
  - Critical mass (500 US physicists).
  - Good facilities (at FNAL and universities).
  - New technology for collaboration (distributed analysis, video conference).
- Its our job to make sure the US takes full advantage of this opportunity.
- Software and Computing project is essential.

And a Great Challenge



- Millions of channels of fast, rad-hard detectors.
- Electronics to cope with 40 MHz rate.
- **Software** to process 100 kHz of highly complex events for HLT.
- **Physics selection** of 100 best events per second.
- **Computing Facilities** and **Analysis Tools** to use multi-Petabyte data base.
- **Startup** fast in 2005.
- **Higgs & SUSY** early.

CMS Transition to OO Software

- Stopped FORTRAN development in 1998.
- Prototype OO software useable in 2000.
- Use OO software for physics and trigger studies.
  - Serious users help us craft appropriate software.
  - Build up a community of experienced OO programmers.
    - And knowledgeable CMS software developers.
  - Develop "final software" for trigger and physics.
- This strategy puts a great deal of pressure on software to serve urgent needs for TDRs.
  - L1 Trigger in 2000
  - Higher Level Trigger and DAQ in 2001
  - Software and Computing in 2002
  - Physics in 2003
- VERY different from Atlas.

Physics Organization in CMS

- Some Physics studies continue with in GEANT3 simulation.
- Focus is on Physics Reconstruction and Selection Groups (PRS).
  - Reconstruction of Physics Objects.
  - Development of HLT algorithms and software.
- PRS collaborates with Core Software and DAQ on overall CMS software.

- Input from ORCA is like real data.
  - We are dealing with calibration, pileup, track finding, optimized energy calculation, radiation in Si…
  - There is a long way to go.

Overall Software Organization

		US
■Core Software		***
■Physics Reconstruction and Selection		
● E-Gamma	Ecal	**
● JetMEt	Hcal	***
● Muon	Muon	***
● B-Tau	Tracker	?
■DAQ and Online		***

■Several Task Forces across boundaries.

■US is directly involved in all of these.

The US in CMS

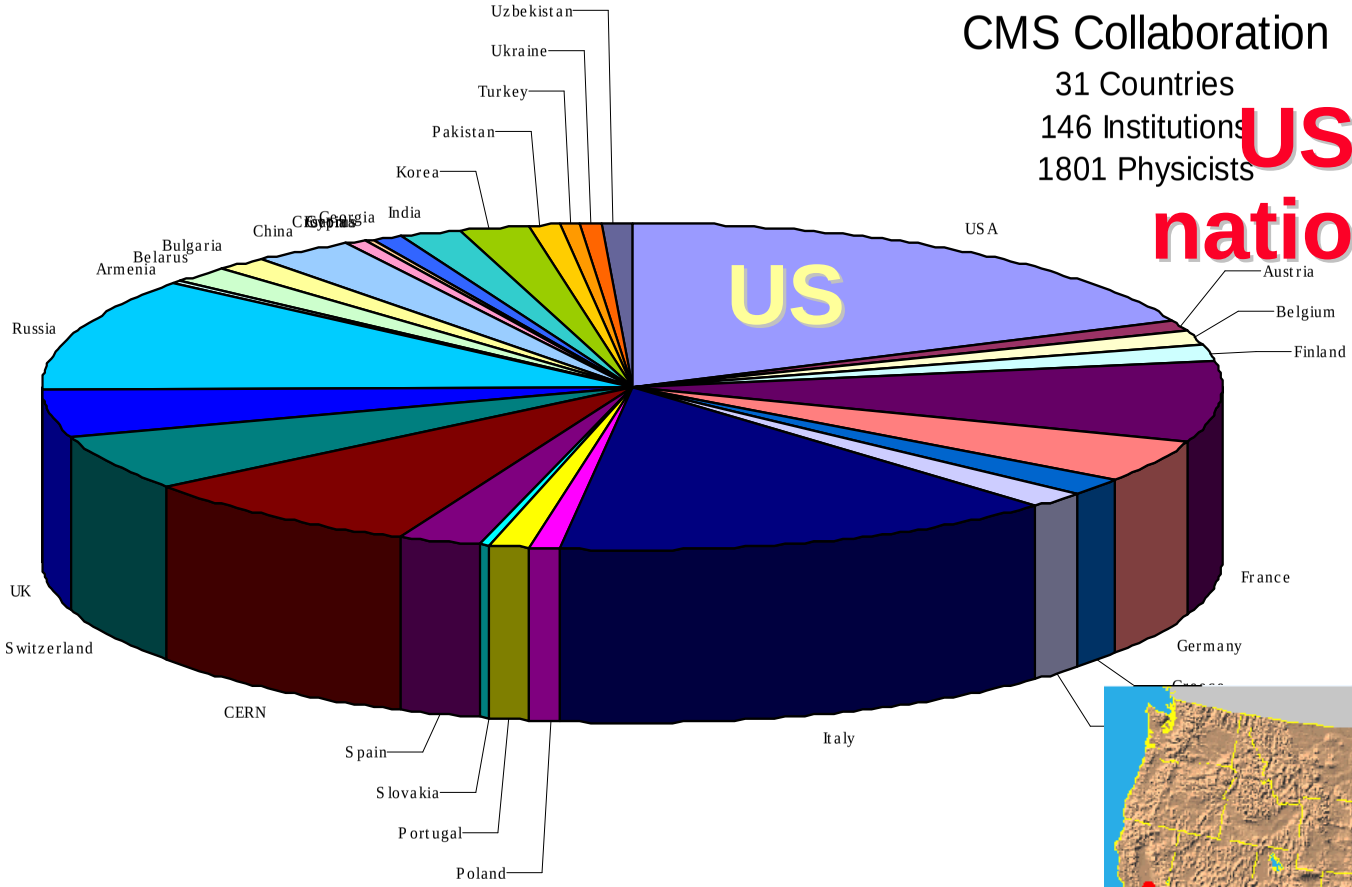
CMS Collaboration

31 Countries

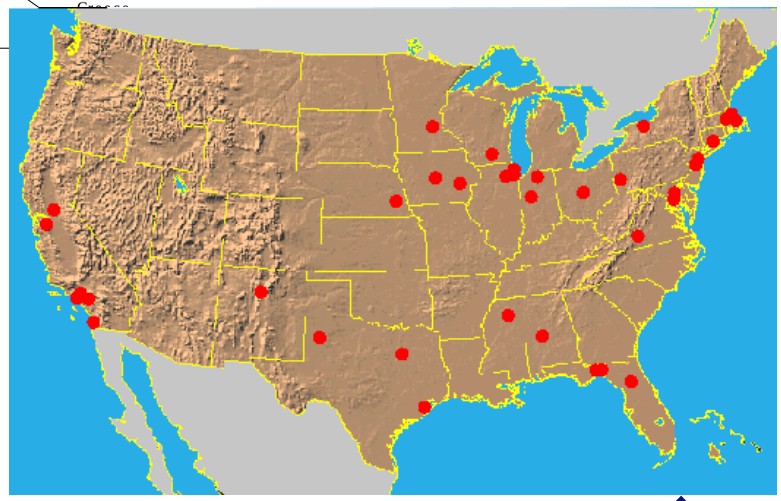
146 Institutions

1801 Physicists

US is largest national group in CMS



Widely dispersed in US



Current US Physics Goals

- Significant role in OO reconstruction and physics object creation.
- Analysis in most if not all of the PRS groups.
- Develop Physics collaboration with Europe.
  - Frequent joint meetings.
- Build expertise in the US.
- Use new OO physics analysis tools.
  - And help plan better ones.
- Test out distributed analysis strategies.
- Input for TDR's.
- New Physics ideas.

US Physics Meetings

- We have started bi-weekly video meetings in the US.
  - Learn about physics, software.
  - Organize US activities.
  - Forum for physicists opinions.
  - Test-bed for video meetings (these work well).
- 7 meetings so far (missing 1st one today).
- Good talks from experts.
- Charting our course in CMS physics.
- Plan to move into specific software and PRS roles.
- Use of engineering resources for architecture…

The Great ORCA Tutorial

- 60 physicists attend FNAL tutorial.
  - Tutors from CERN (4)
  - All US CAS Engineers (7)
  - Some already expert US physicists (~10)
  - US CMS Physicists who wanted to learn software (~40)
- Excellent tutorial material
  - How to work with CMS Software
  - Building Applications
  - Replicating databases (shallow, deep, user)
  - Homework
- Engineering meetings
- Physics meeting + interaction with engineers.
- Not perfect but very good.

Some Things I Learned at the Tutorial

- ORCA/CARF presents a nice usable framework for physics software.
- Interactive analysis is coming soon.
  - We'll need another tutorial to get beyond PAW.
  - Tags are available and useful.
- SCRAM provides a lot of flexibility to produce executable modules for our needs.
  - Eventually it will require a user friendly front end.
- Objectivity tools exist to make user data bases that are part shallow and part deep copies.
  - It looks like an excellent tool.
- US people doing endcap muon code have managed to reuse tracker classes; very impressive.
- I could do the homework.

CMS Software and Physics Meetings

- All PRS meetings at 4:00 PM or 4:30 PM Geneva time on either Tuesday or Wednesday (biweekly).
- RPROM, SPROM on Mondays.
- CAFÉ (Architecture) on Thursday.

- Now, we need to have good US attendance and productivity.

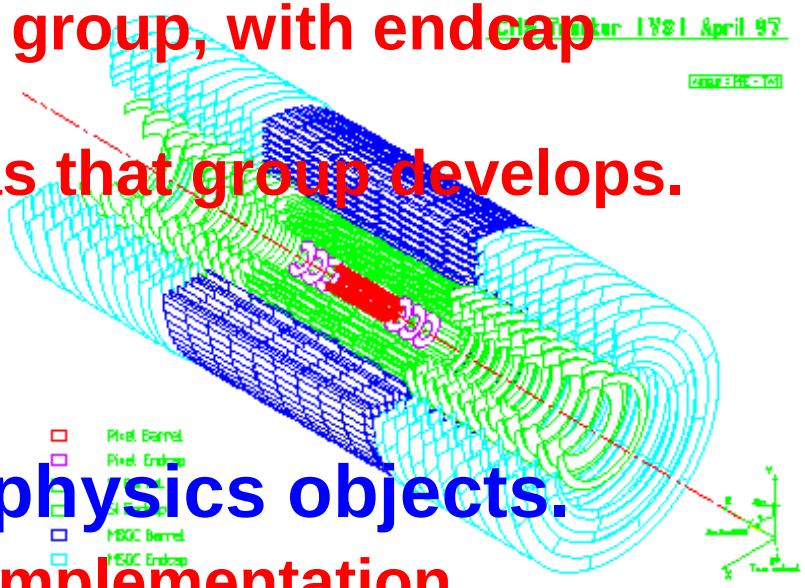
- US (only) meetings also an option.

Improving Video Meetings

- We use VRVS for all the meetings.
- US meetings work well.
- Large central meeting rooms are usually the problem.
- CERN has one acceptable room plus one bad.
  - Caltech is making an effort to equip 1-2 more with Polycom viewstations. (New VRVS version)
- Fermilab rooms often don't work well.
- Meetings are improving.
- Startup cost is low yet ultimate level of interactivity is quite good.
- We will continue to work on this.

Vigorous PRS Effort

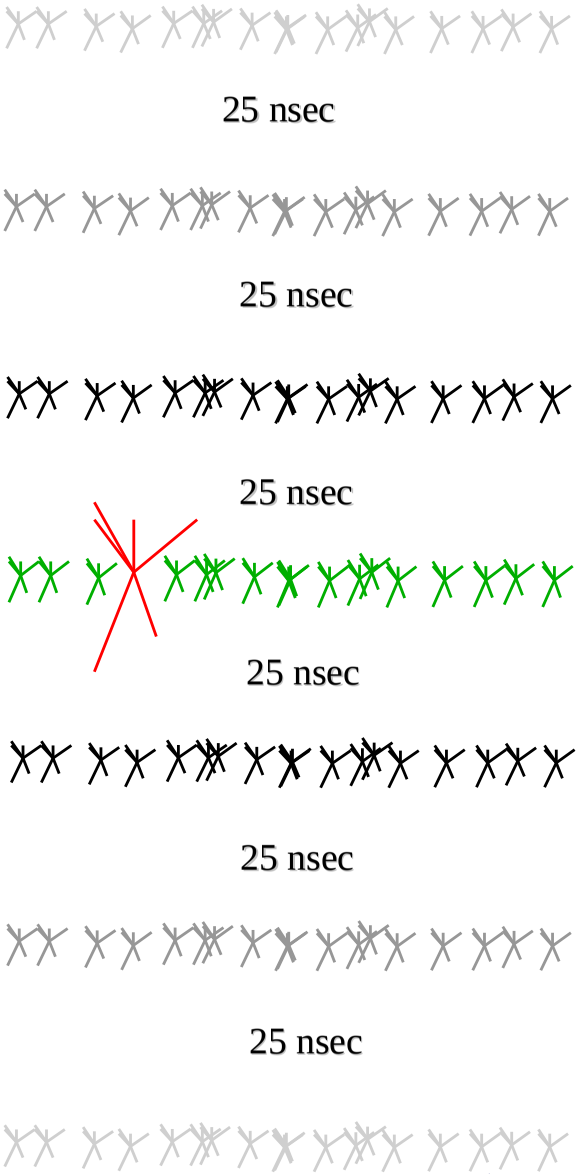
- **US will increase the level of effort in Physics Reconstruction and Selection**
  - **Add more people who work in software to JetMEt group where we have leadership.**
  - **Begin effort in e/γ group.**
  - **Continue solid work in muon group, with endcap emphasis.**
  - **Possibly start tracker effort as that group develops.**
    - Pixels important for trigger
    - Part of e/γ



- **General software effort on physics objects.**
  - **Algorithm development and implementation**
  - **Engineering and architecture.**

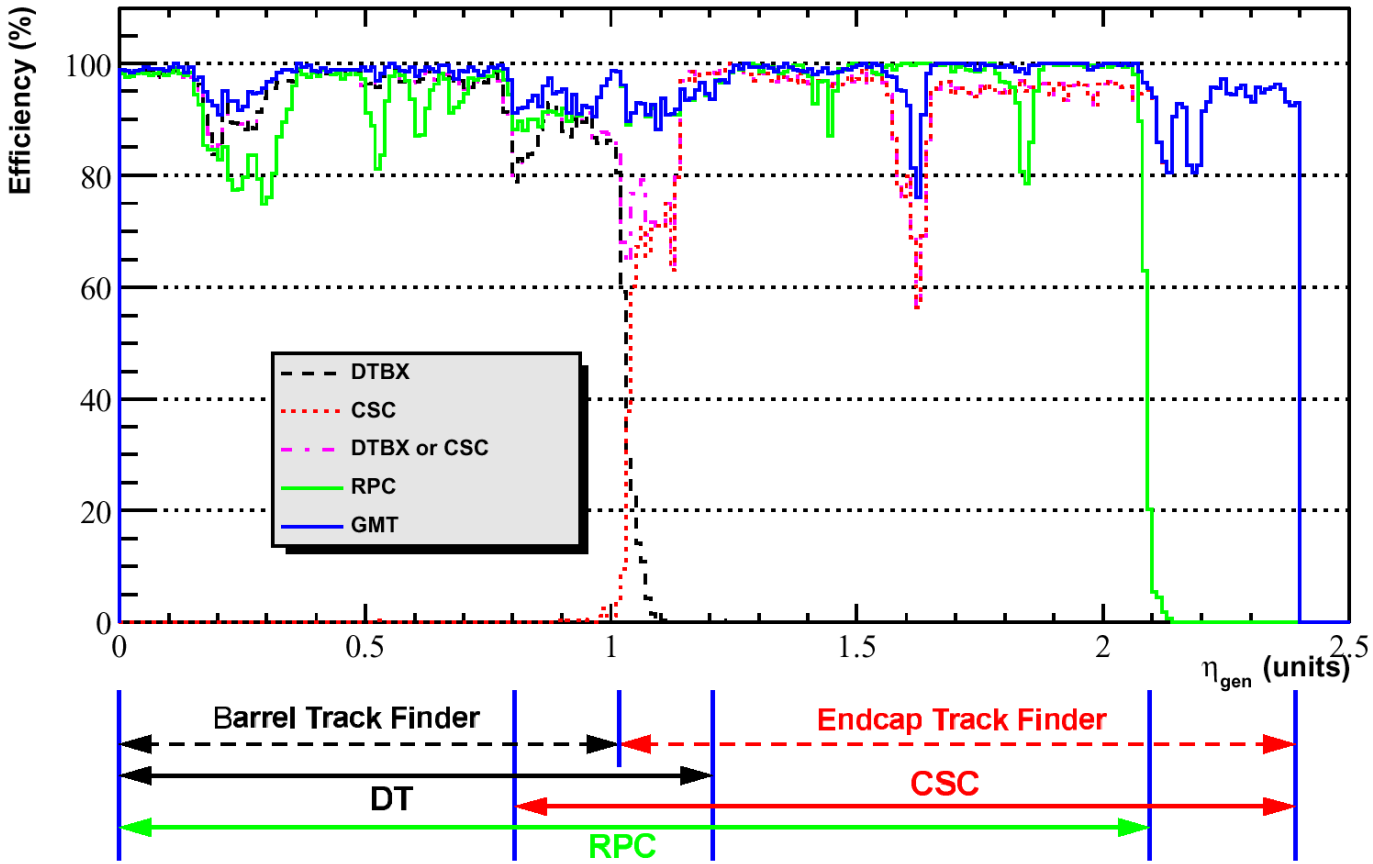
PRS Studies All with OO Software

- OO hit production.
- Digitization
  - 17 in time pile up events
  - Hundreds of out of time pile up events
- Reconstructed objects
- OO software in PRS groups
- (We still use ntuples for now)
  - Tags in data base and more powerful analysis techniques are coming.



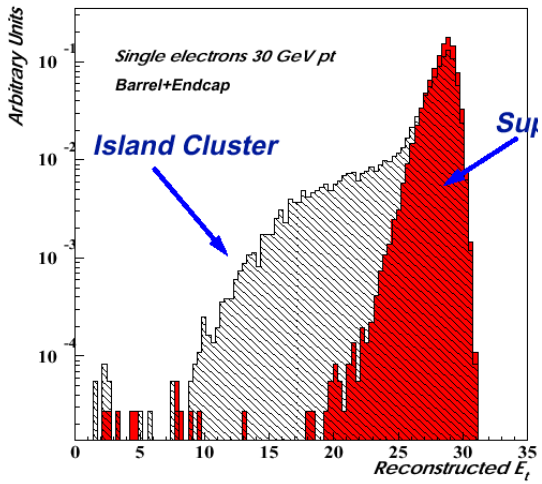
Muon Software and Physics

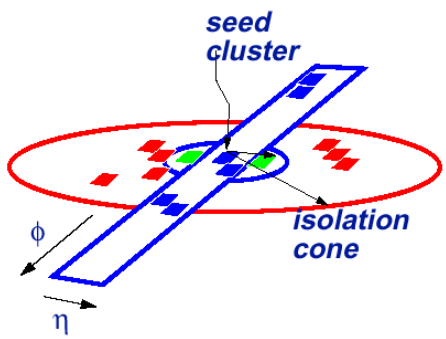
- Very good software work in US.
- Lots of hard work at level 1.
- Factor of 10 so far at level 2.

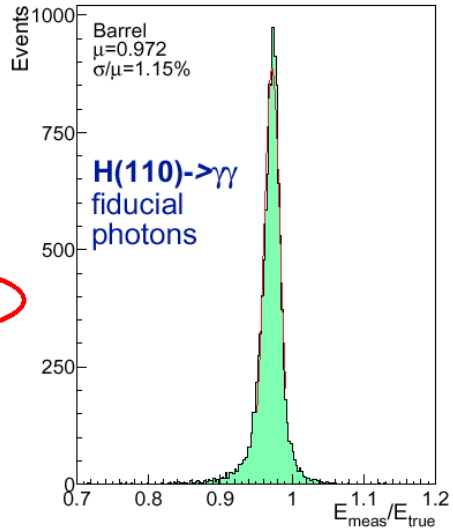


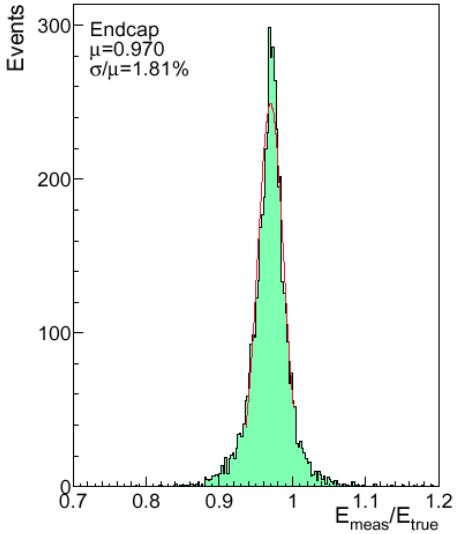
e/γ Physics

- Reclaim energy radiated in tracker.
- Use isolation to get level 2 factor of 6.65.
- Quick level 2 factor of 12 reduction from pixels.
- Maintains high efficiency for Higgs signals.
  - 97.5% for H→ ZZ*→ 4e (170) (no fiducial cuts)
  - 96% for H→ γγ (110) (fiducial cuts)



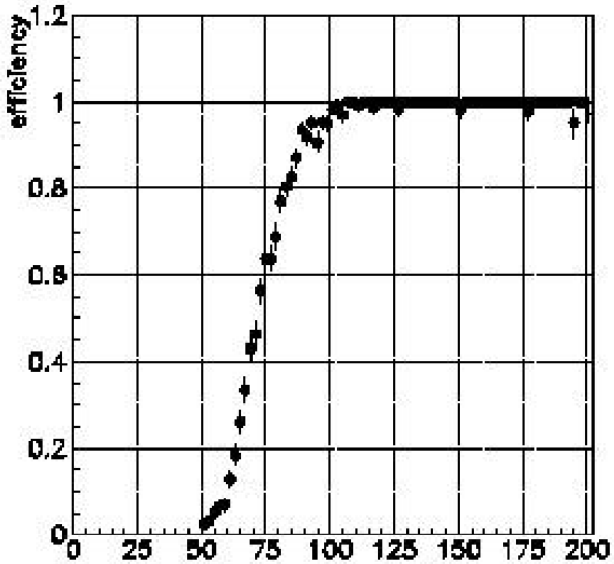


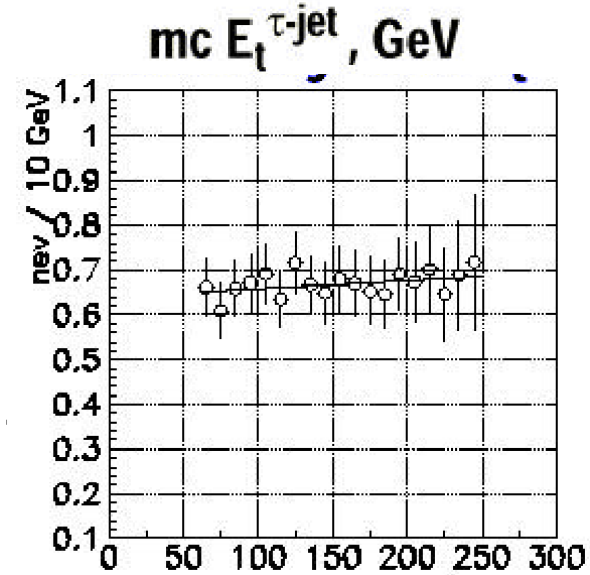




Jet and Missing Energy Trigger

- Studies have caused change in level 1 trigger.
  - τ identified jets with much lower threshold.
  - Good efficiency for $H \rightarrow \tau\tau$.
- Calibration of calorimeter
- Much work on level 1 rate with pileup.
- Level 2 reductions are small so far.
- US needs to put more effort into this area where we have a large hardware contribution.





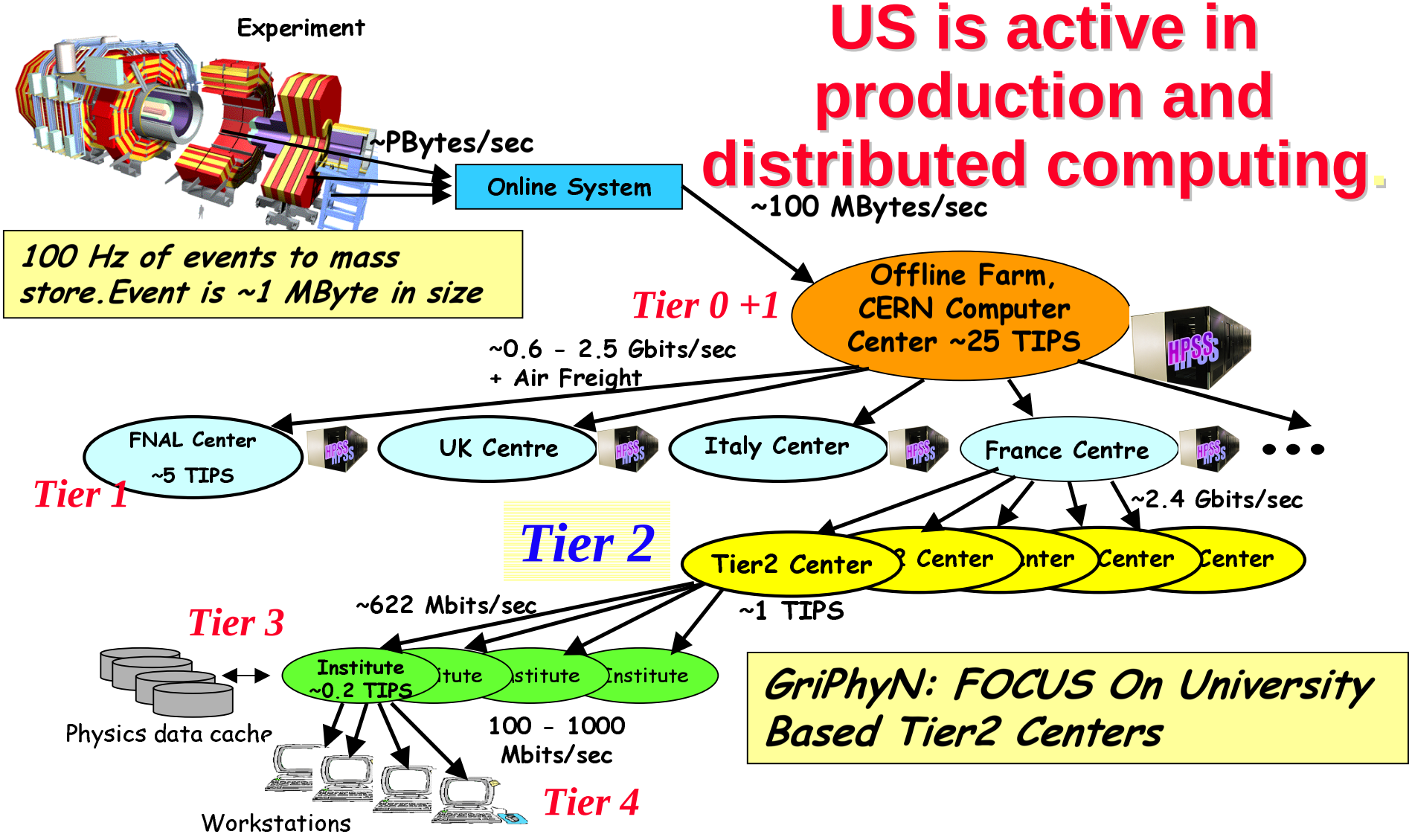
US Calorimeter Software Initiative

- We plan to become very active in the overall calorimeter software.
  - Signal handling.
  - Trigger primitives.
  - Calibration.
  - Basic clusters.
  - Architecture.
- Extension into JetMEt and e/γ.

- CAS engineering help planned.

US and Worldwide Data Grid

US is active in production and distributed computing.



Conclusions

- The LHC is a great physics opportunity.
- Since LHC experiments are a large part of the US program, we must play a major role in the physics analysis, both at CERN and in the US.
- The US is already very active in CMS physics.
- We are organized and becoming more involved.
  - US meetings
  - CMS software and PRS meetings available to US
  - Very involved in OO software.
  - Very involved in distributed computing.
  - Success with Tutorials.
- We need to build and sustain the physics effort.
- The US S&C Project is vital to our success.
- All our physics results use the OO software.