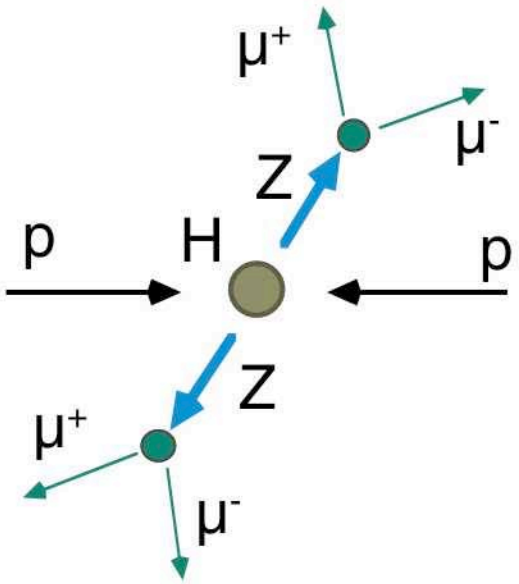
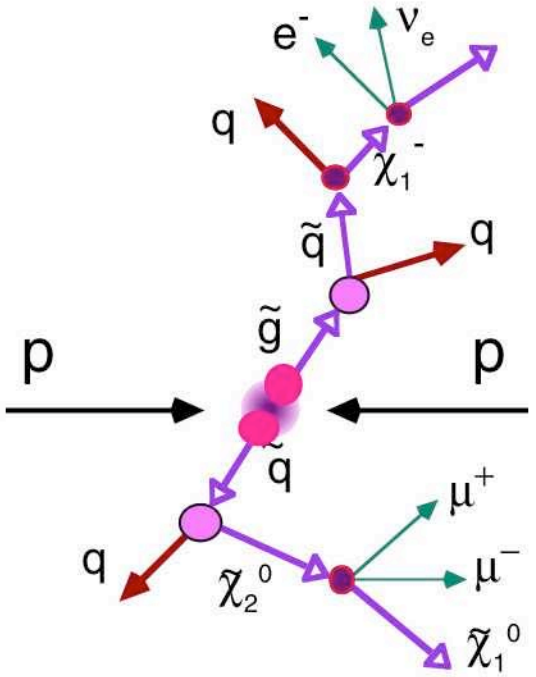
Physics at LHC

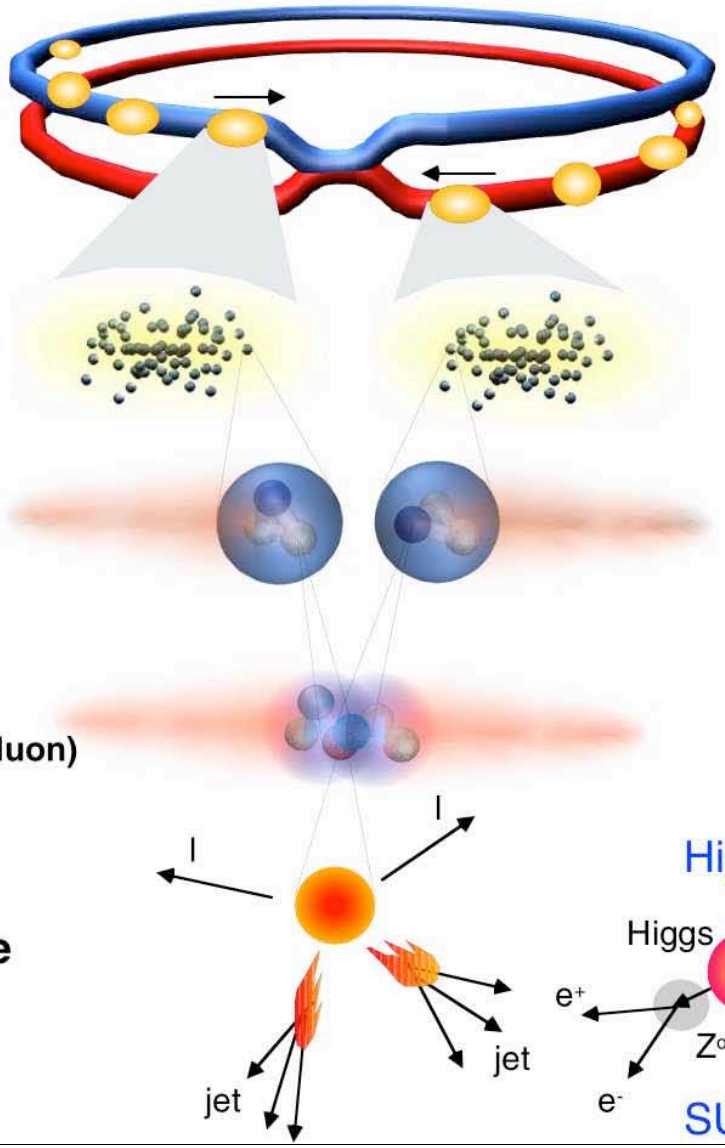


- **HIGGS** : Clarify the origin of the spontaneous symmetry-breaking mechanism in the EW sector of the Standard Model (-> Higgs, SUSY)

- **NEW FORCES (symmetries)**
- New particles
- Super symmetries
- Substructure
- Extra dimensions
- Composite quarks & leptons
- …….?



LHC Collisions

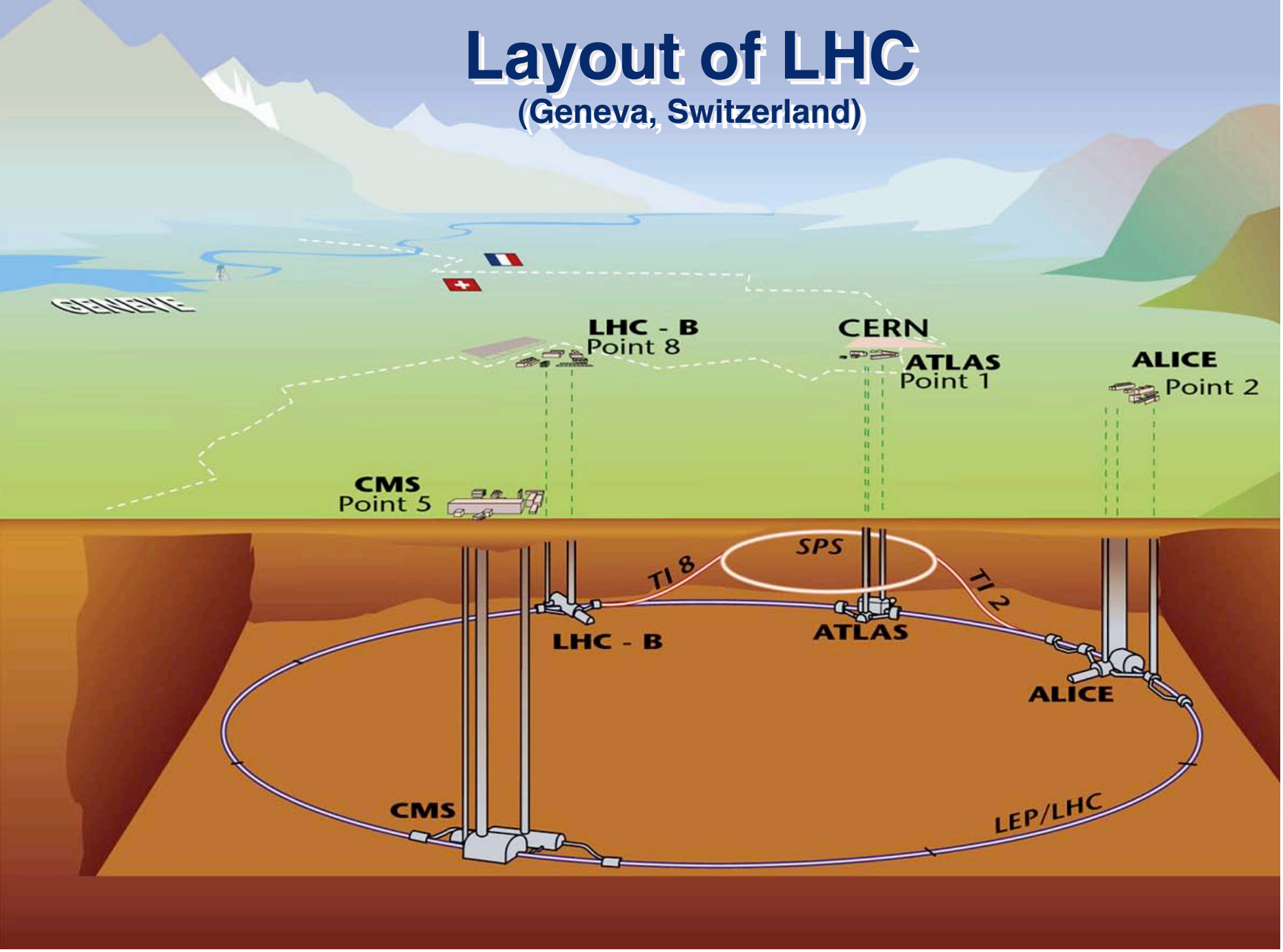


Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}
Crossing rate	40 MHz
Collisions ≈	10^{7} - 10^{9} Hz

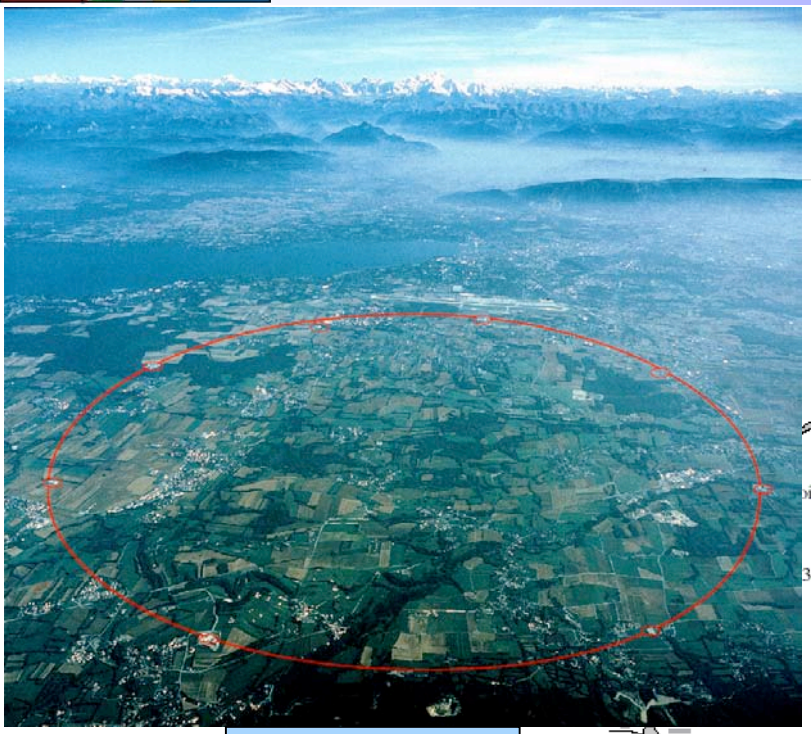
Selection of 1 in 10,000,000,000,000

Layout of LHC

(Geneva, Switzerland)

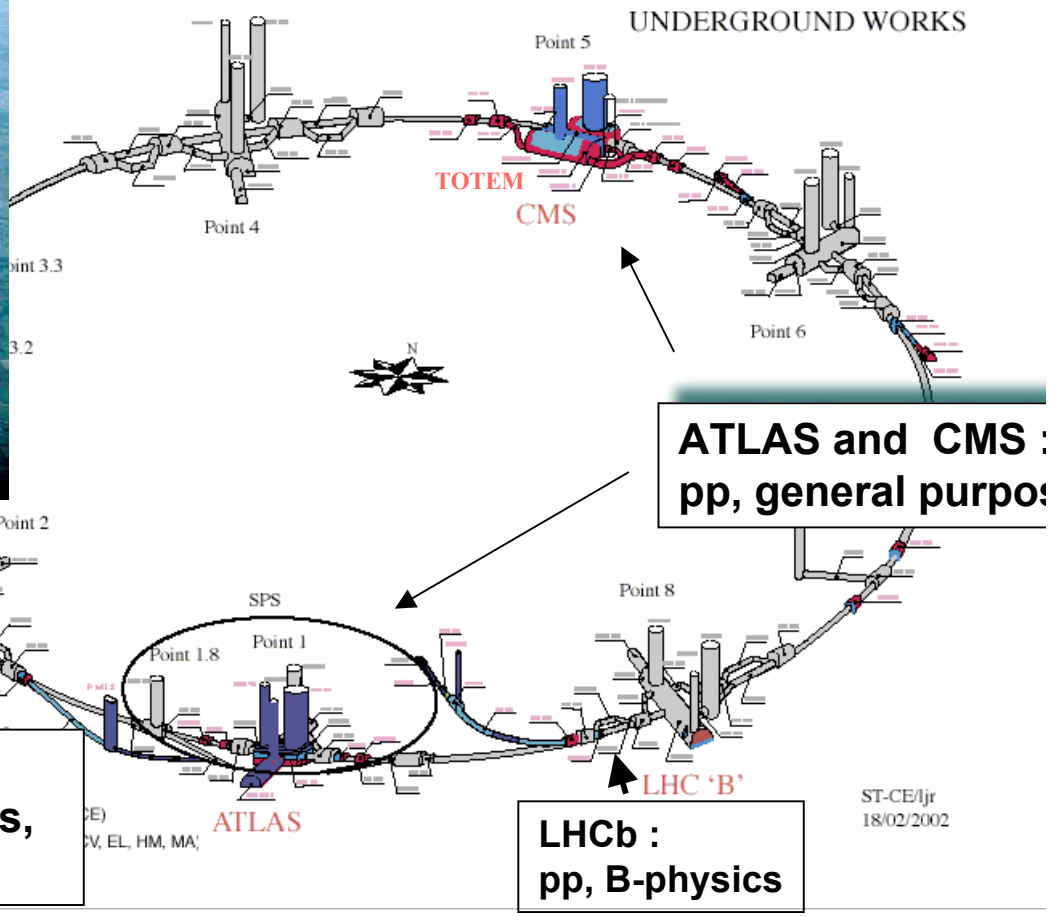


Experiments at the LHC



27 Km ring
1232 dipoles B=8.3 T
(NbTi at 1.9 K)

- pp $\sqrt{s}$ = **14 TeV** $L_{design} = 10^{34}$ cm^{-2} s^{-1}
- **Heavy ions** **(e.g. Pb-Pb at $\sqrt{s}$ ~ 1000 TeV)**



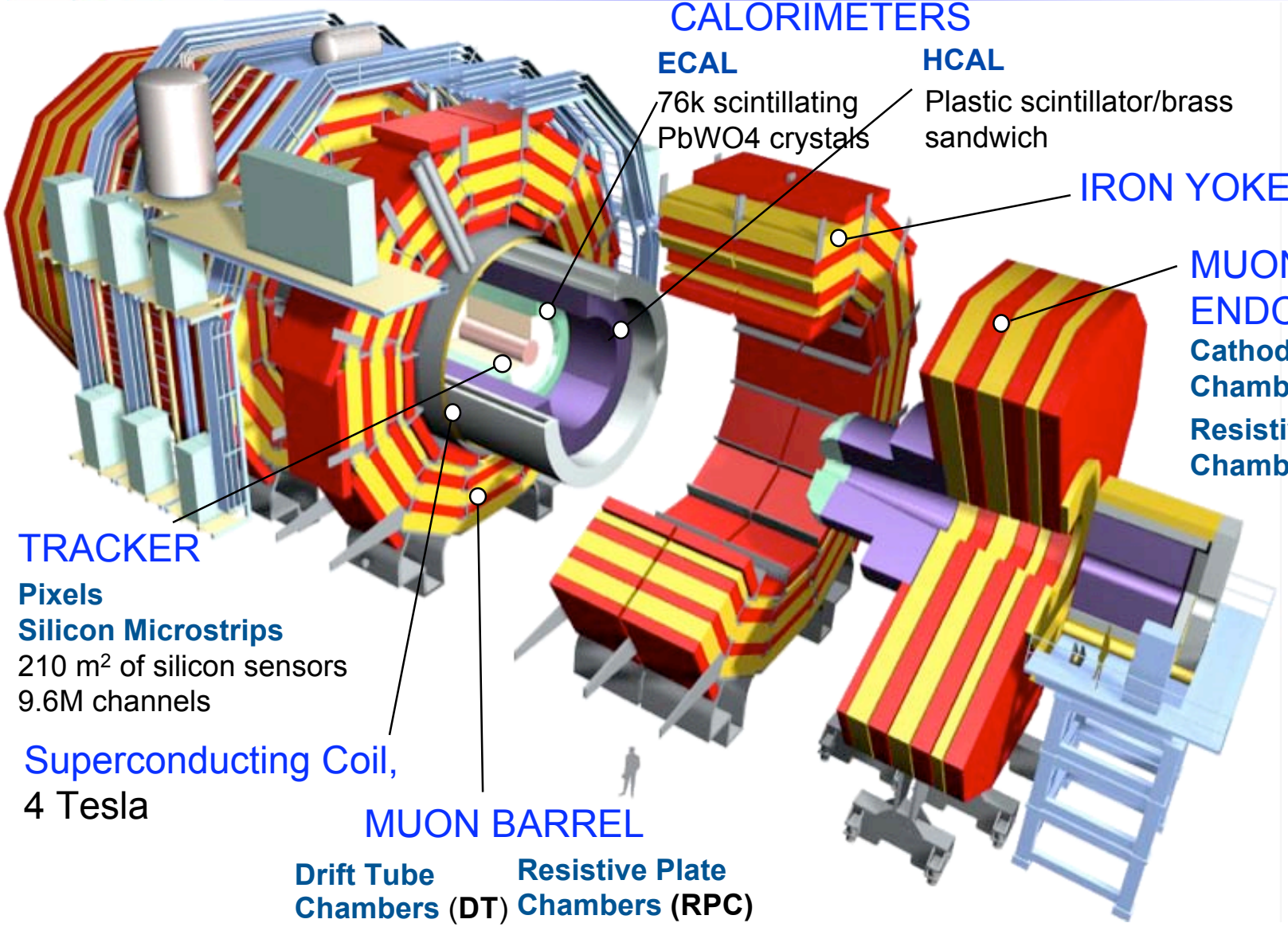
ATLAS and CMS :
pp, general purpos

First Collisions 2007
Physics in 2008

ALICE :
heavy ions,
p-ions

LHCb :
pp, B-physics

CMS Detector



CALORIMETERS

ECAL
76k scintillating PbWO4 crystals

HCAL
Plastic scintillator/brass sandwich

IRON YOKE

MUON ENDCAPS

Cathode Strip Chambers (CSC)

Resistive Plate Chambers (RPC)

TRACKER

Pixels

Silicon Microstrips

210 m^2 of silicon sensors
9.6M channels

Superconducting Coil,
4 Tesla

MUON BARREL

Drift Tube Chambers (DT)

Resistive Plate Chambers (RPC)

Wisconsin on CMS at LHC

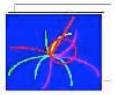
Personnel:

- Professors D. Carlsmith, S. Dasu, D. Reeder, W. Smith
- Senior Scientist R. Loveless
- Senior Electronics Engineer T. Gorski
- Assistant Scientists P. Chumney, M. Grothe, A. Lanaro
- Postdoc Y. Baek
- Computing Professionals: D. Bradley, A. Mohapatra, S. Rader
- Engineer M. Jaworski, Technician R. Fobes
- Grad Students: C. Hogg, J. Leonard (& you?)
- PSL Engineers F. Feyzi, J. Hoffman, P. Robl, D. Wahl, D. Wenman
- PSL Draft/Tech: G. Gregerson, D. Grim, J. Pippin, R. Smith

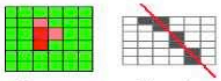
Activities:

- Calorimeter Trigger (W. Smith, CMS Trigger Project Manager)
- Endcap Muon System (R. Loveless, CMS Endcap Muon Manager)
- Computing/Physics (S. Dasu, US CMS Computing Adv. Bd, Chair)

Trigger & DAQ at the LHC

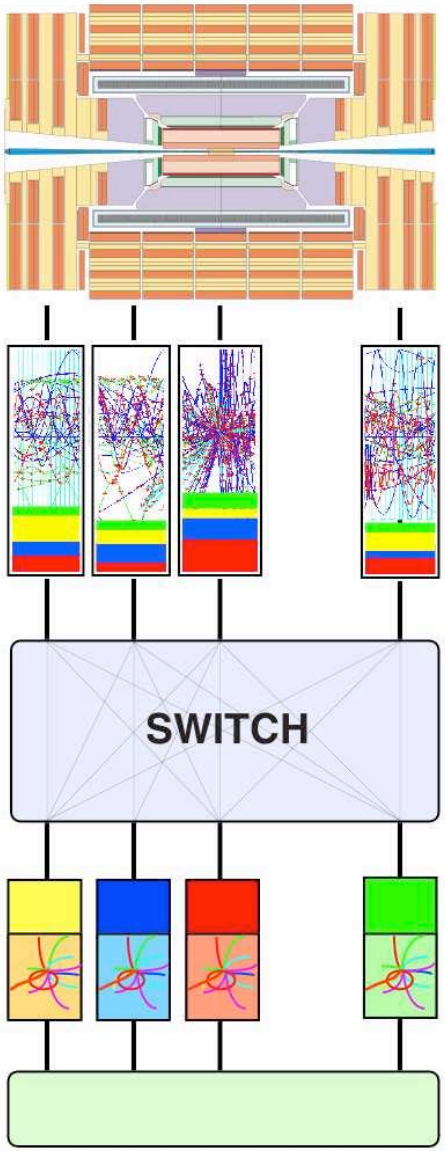


40 MHz
COLLISION RATE



100 kHz
LEVEL-1 TRIGGER

1 Terabit/s
(50000 DATA CHANNELS)

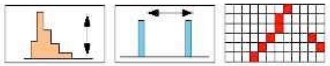


500 Gigabit/s

100 Hz
FILTERED EVENT

Gigabit/s SERVICE LAN

16 Million channels
3 Gigacell buffers



1 Megabyte EVENT DATA

200 Gigabyte BUFFERS
500 Readout memories

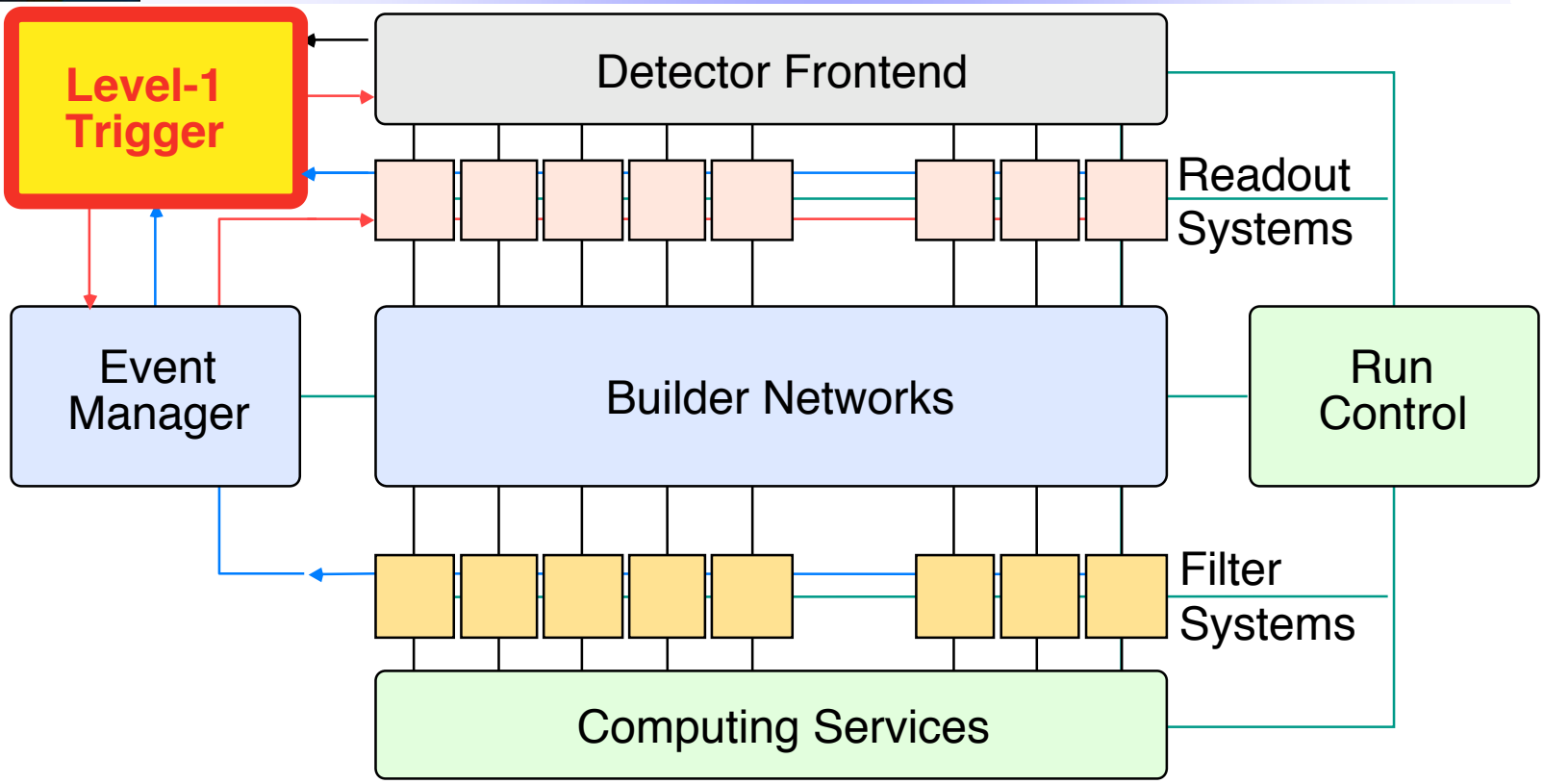
EVENT BUILDER. A large switching network (512+512 ports) with a total throughput of approximately 500 Gbit/s forms the interconnection between the sources (Readout Dual Port Memory) and the destinations (switch to Farm Interface). The Event Manager collects the status and request of event filters and distributes event building commands (read/clear) to RDPMs

5 TeraIPS

EVENT FILTER. It consists of a set of high performance commercial processors organized into many farms convenient for on-line and off-line applications. The farm architecture is such that a single CPU processes one event

Petabyte ARCHIVE

CMS Trigger & DAQ Systems



Level-1 Trigger Requirements:

- Input: 10^9 events/sec at 40 MHz at full L = 10^{34}
- Output: 100 kHz (50 kHz for initial running)
- Latency: 3 μsec for collection, decision, propagation
- Output direct to computer filter farm (no physical level-2)

CMS Level-1 Trigger

W. Smith, Project Manager

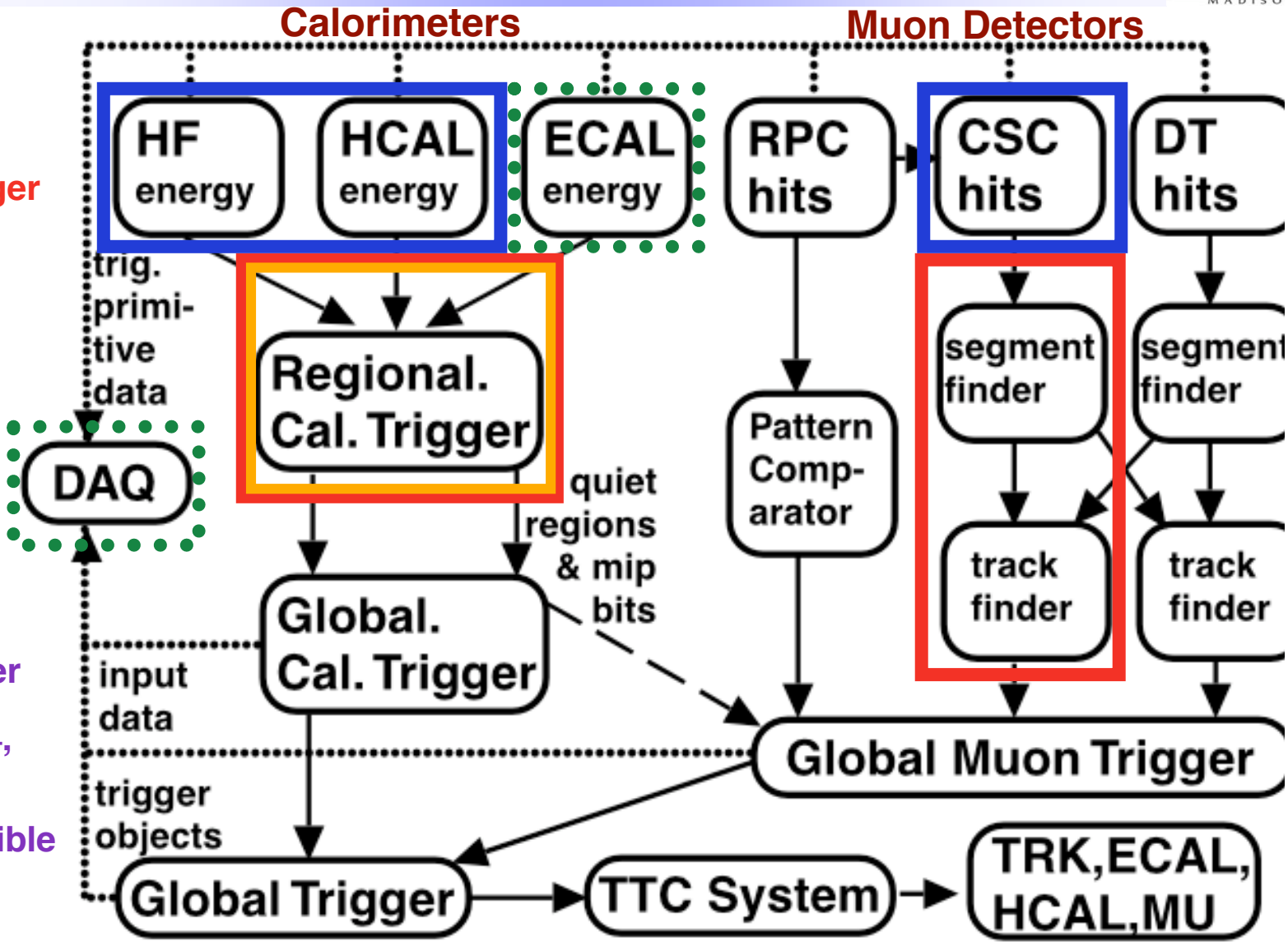
Wisconsin fully responsible

US CMS Trigger

US CMS fully responsible

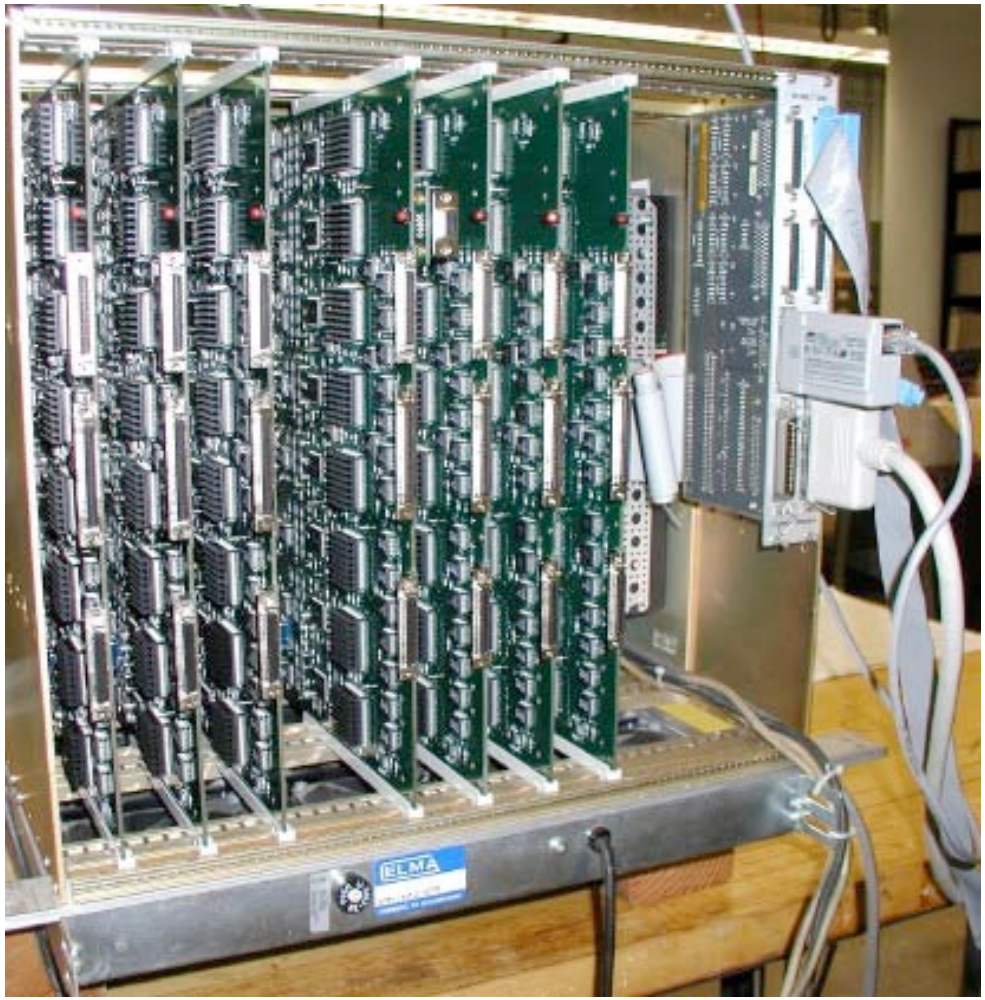
US CMS partially responsible

UNIQUE: All system present trigger objects w/location, E_T, quality -- topological triggers possible



Calorimeter Trigger Crate

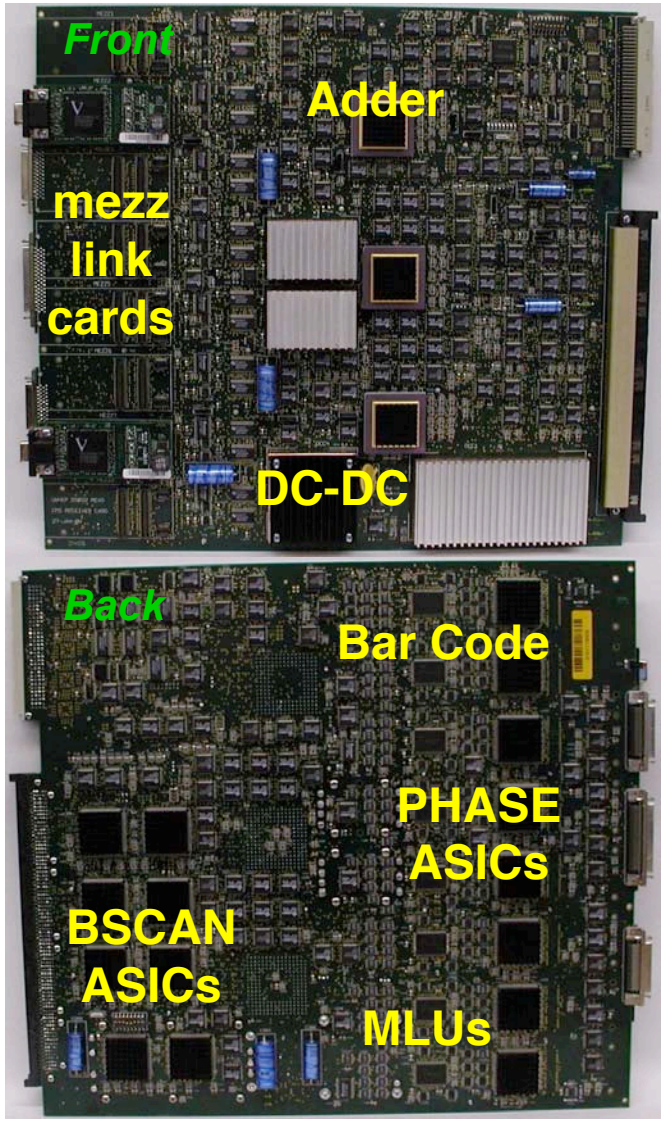
One of 18 160 MHz systems processing 0.4 Tbits/s.



Rear: Receiver Cards

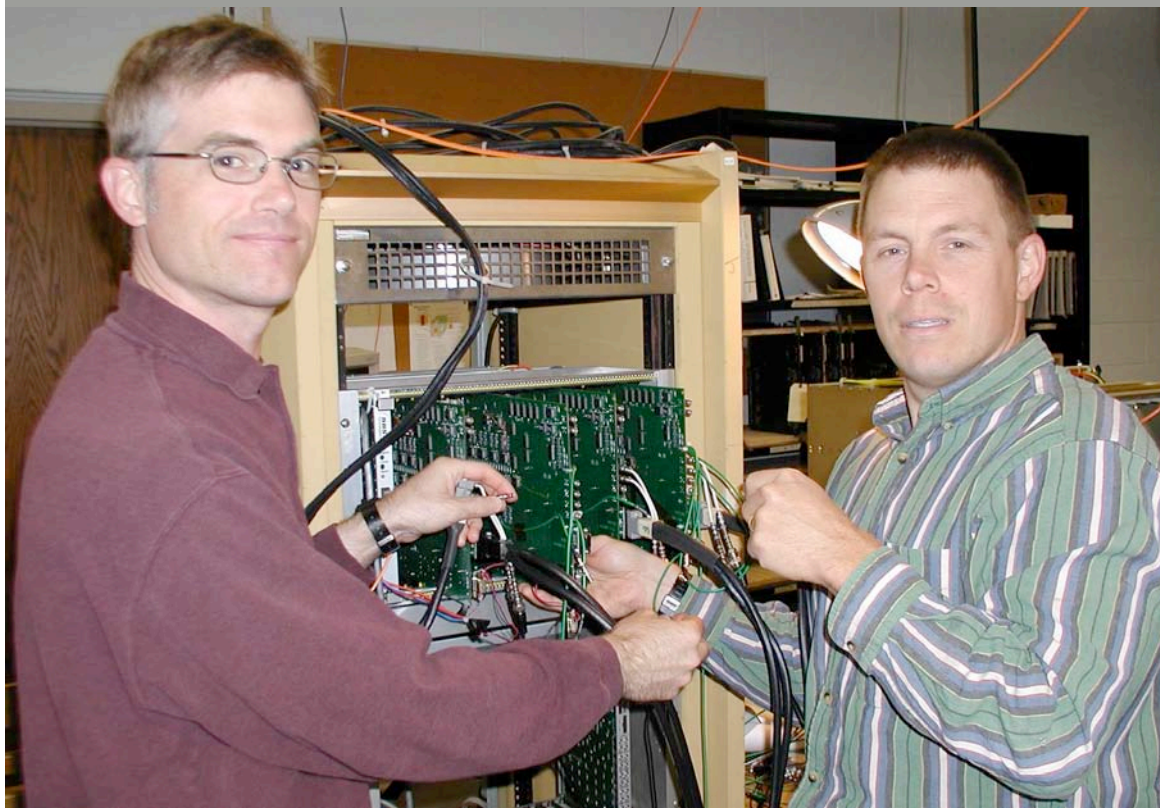
Front: Electron, Jet, Clock Cards

Calorimeter Trigger Receiver Mezzanine Card (RMC) and Receiver Card (RC)

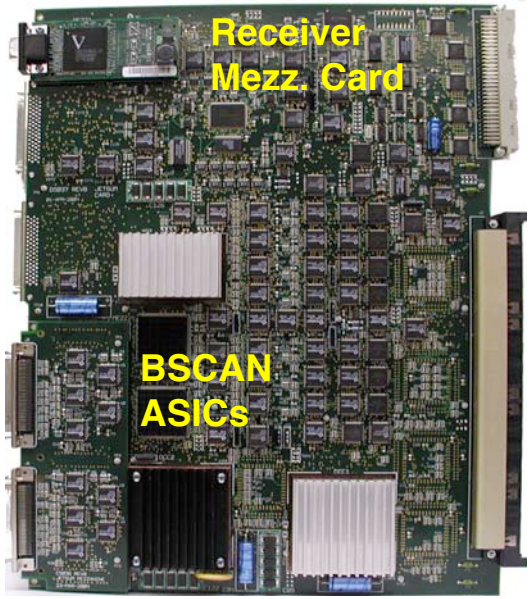


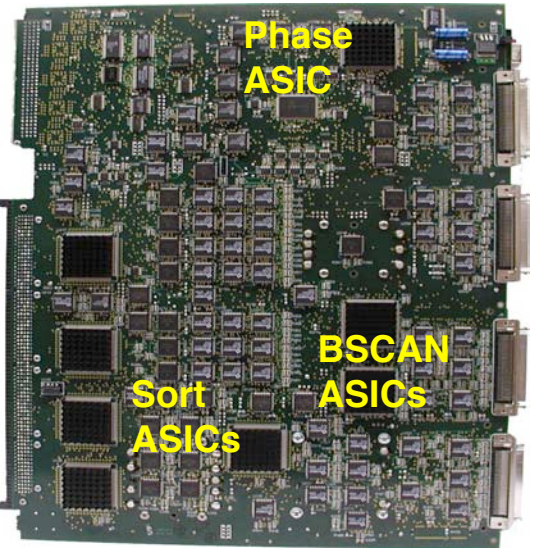
Receives 64 Calorimeter energy sums every 25 n using 8 Vitesse 1.2 Gbaud links on Receiver Mezzanine link Cards, sends to Jet/Summary Car

Tech'n. R. Fobes (l.) & Eng'r. T. Gorski (r.) test links:



Work on Calorimeter Trigger





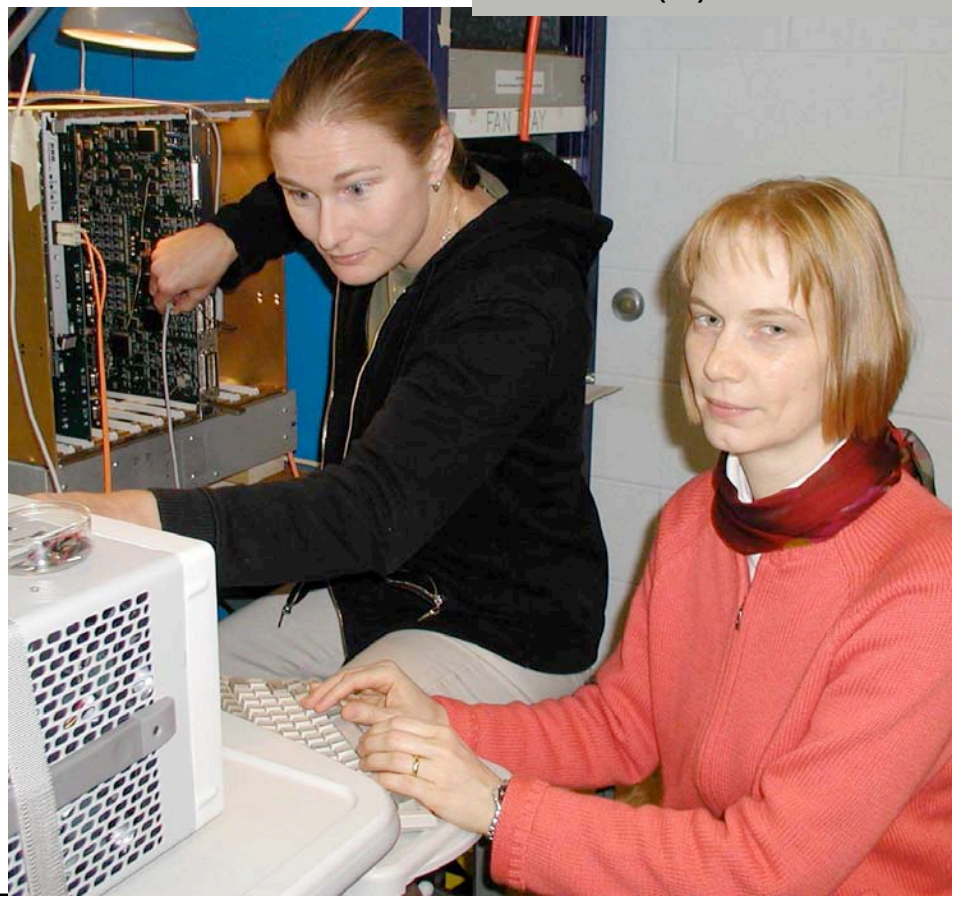
Wisconsin scientists along with students are involved in

- **Testing electronics cards**
- **Writing real-time control and diagnostic software**
- **Writing detailed hardware emulation**
- **Physics simulation of trigger signals**

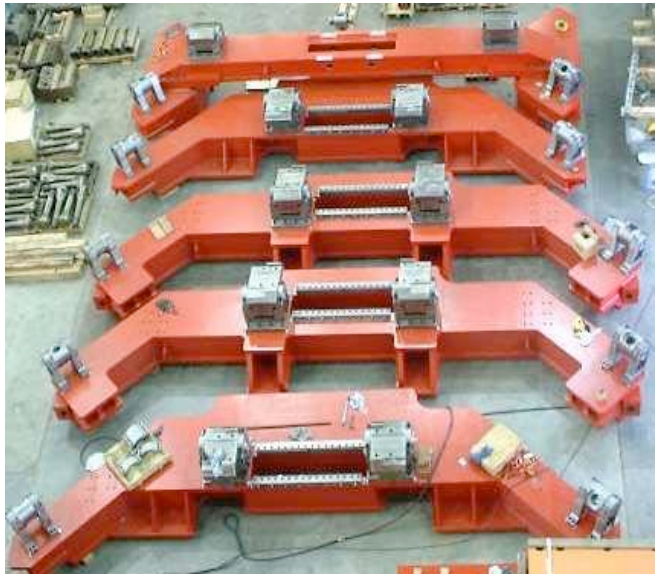
Left:

Jet Summary Card back and front sides showing custom high-speed Wisconsin ASICs

Asst. Scientists
P. Chumney (l.) and M
Grothe (r.) test JSC:



UW built the endcap disks



UW installs the chambers

L to R: F. Feyzi, D. Wenman, A. Lanaro
J. Johnson, M. Giardoni, “Regis”, Y. Baek

UW CMS Physics Activities

Wide-ranging physics interest and expertise in the group

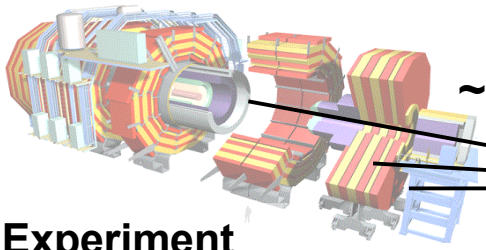
- **Analysis efforts coming to forefront as detector work finishes**
- **Ensure trigger systems operate at full performance at turn-on**
- **We studied simulated Higgs, SUSY, SM EW and QCD datasets**
  - Designed trigger systems that capture all the important physics efficiently while satisfying DAQ bandwidth requirements
- **Design triggers for physics channels that are new to CMS**
  - Diffractive Higgs ($H \rightarrow bb$), Vector boson fusion Higgs ($H \rightarrow bb$)
- **Full simulation and analysis for low mass Higgs**
  - Above channels and other VBF, $H \rightarrow tt$, $H \rightarrow WW^*$

Physics, Reconstruction & Software

- **Dasu is co-leader of PRS Online Selection Group**
- **Updating trigger emulation and developing trigger validation tools**

Accumulate large physics samples $\Rightarrow$ our computing effort

CMS Computing - Tier-2



Experiment

~PByte/sec

Online System

~100-1500 MBytes/sec

CERN/Outside Resource Ratio ~1:2
Tier0/(Σ Tier1)/(Σ Tier2) ~1:1:1

Tier 0

CERN Center
PBs of Disk;
Tape Robot

Tier 1

IN2P3 Center

RAL Center

FNAL Center

INFN Center

10 Gbps

Tier 2

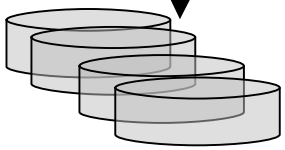
Wisconsin

Florida

Caltech

UCSD

Physics User Support
~50 Users per Tier-2



Physics data cache
~200 TB storage per Tier-2

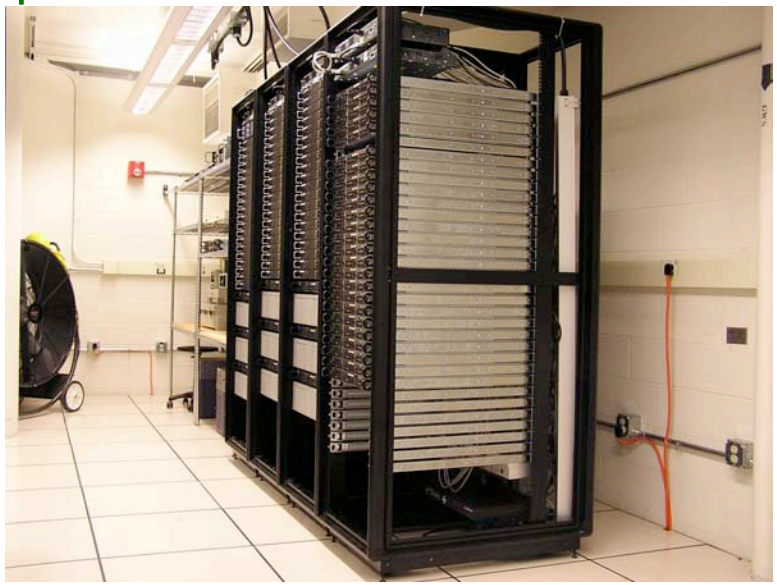
Compute Servers
~500 CPUs per Tier-2
Bulk of MC Simulation

Tier-2 Resources in
Open Science Grid

UW Computing Resources

UW Campus Wide Grid using Condor Technologies - our group is helping develop it

- **Used primarily by CMS, but also by ATLAS & Pheno groups - expect growth**
  - Access to ~500 CPUs on average
    - **Physics (~100), GLOW 6 sites (850), CS (~700) + Tier-2 (+300 by 2007)**
  - Dedicated storage and high-throughput network
    - **50 TB storage @ physics + Tier-2 (~200 TB by 2007)**
    - **~40 TB more on GLOW**
    - **1 Gbps campus backbone 10 Gbps to WAN**
  - Seamless access to resources
    - **Jobs submitted at HEP run all over the campus**



Computing Accomplishments

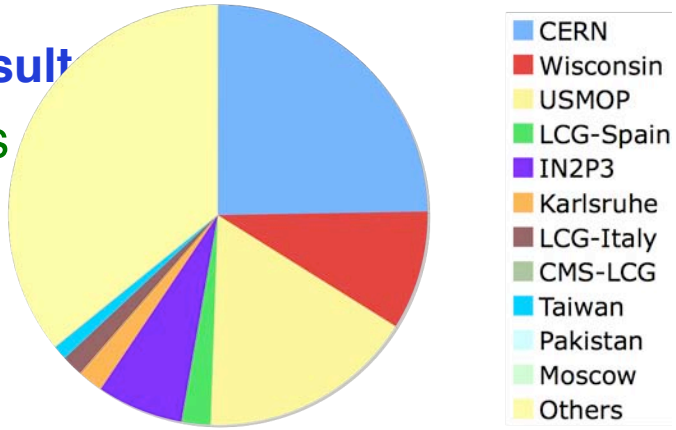
Worldwide impact…and can do more!

UW results used for important decisions

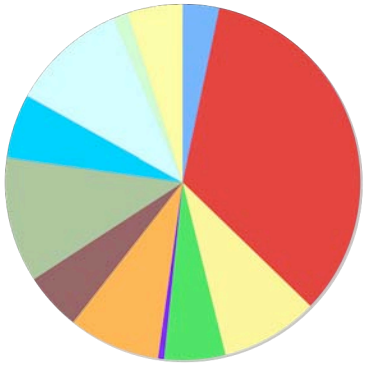
- **Changes in trigger driven by simulation result**
  - Refinement/development of algorithms
- **Overall TriDAS bandwidth determined**
  - Quick study of physics scenarios at various levels of scalable CMS DAQ
- **Grid technology empowers individual groups to command large CPU resources**

Simulation production in 2005

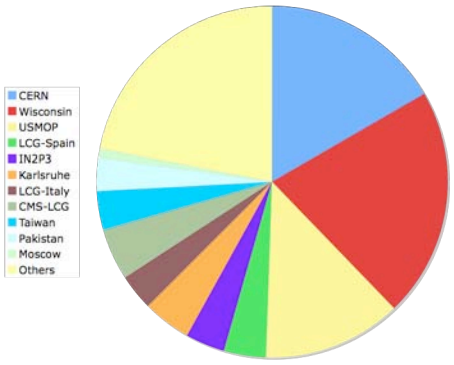
Data Summary Production



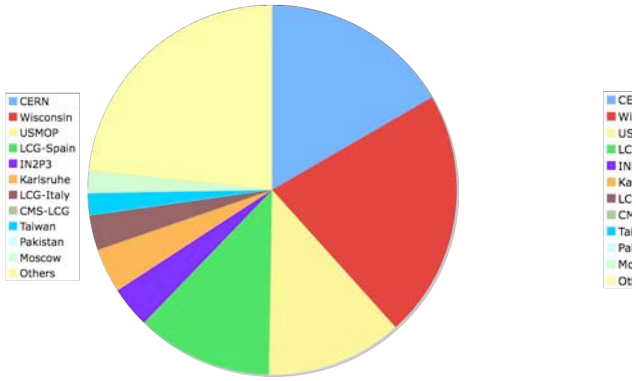
Physics Simulation CMKIN



Detector Simulation OSCAR



Reconstruction (ORCA)



Grad Student Timeline

2005-2007:

- Classes
- Qualifier
- Prelim on LHC Physics Topic

2007-2008:

- CMS starts taking data -- move to CERN!
- Work on CMS trigger or muon systems
- Collect data for thesis
- Start thesis physics analysis

2009-2010:

- Complete thesis physics analysis on new discovery!
- Write thesis & graduate