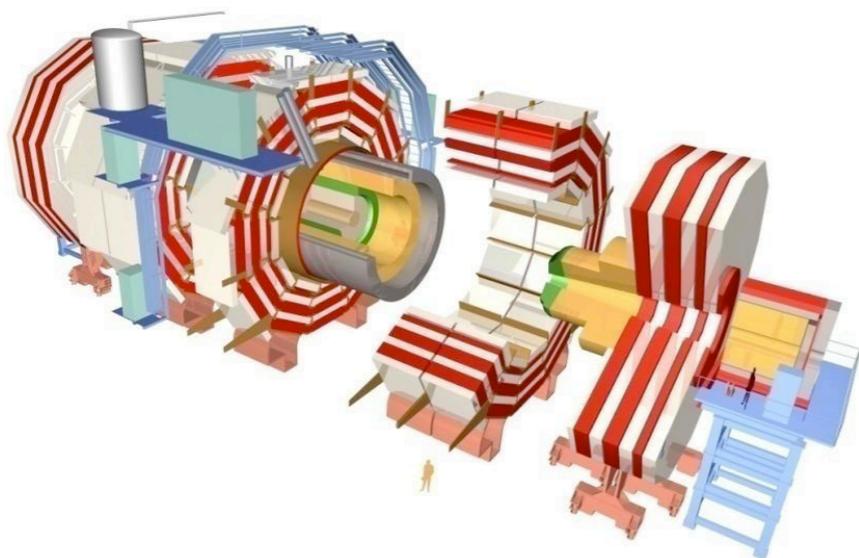


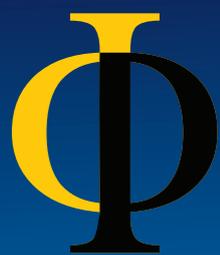
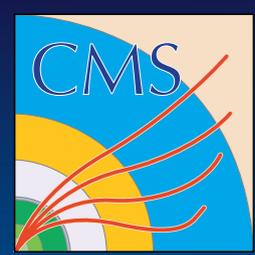


Compact Muon Solenoid

The commissioning of the CMS ECAL detector with cosmics and first LHC beams

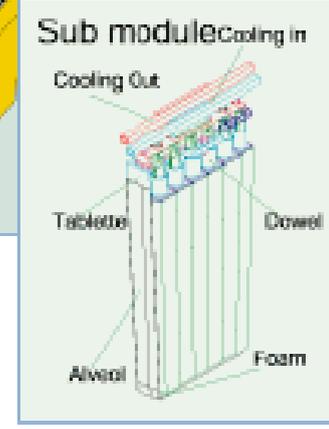
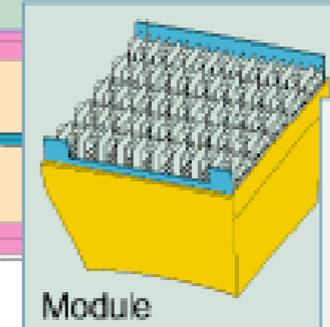
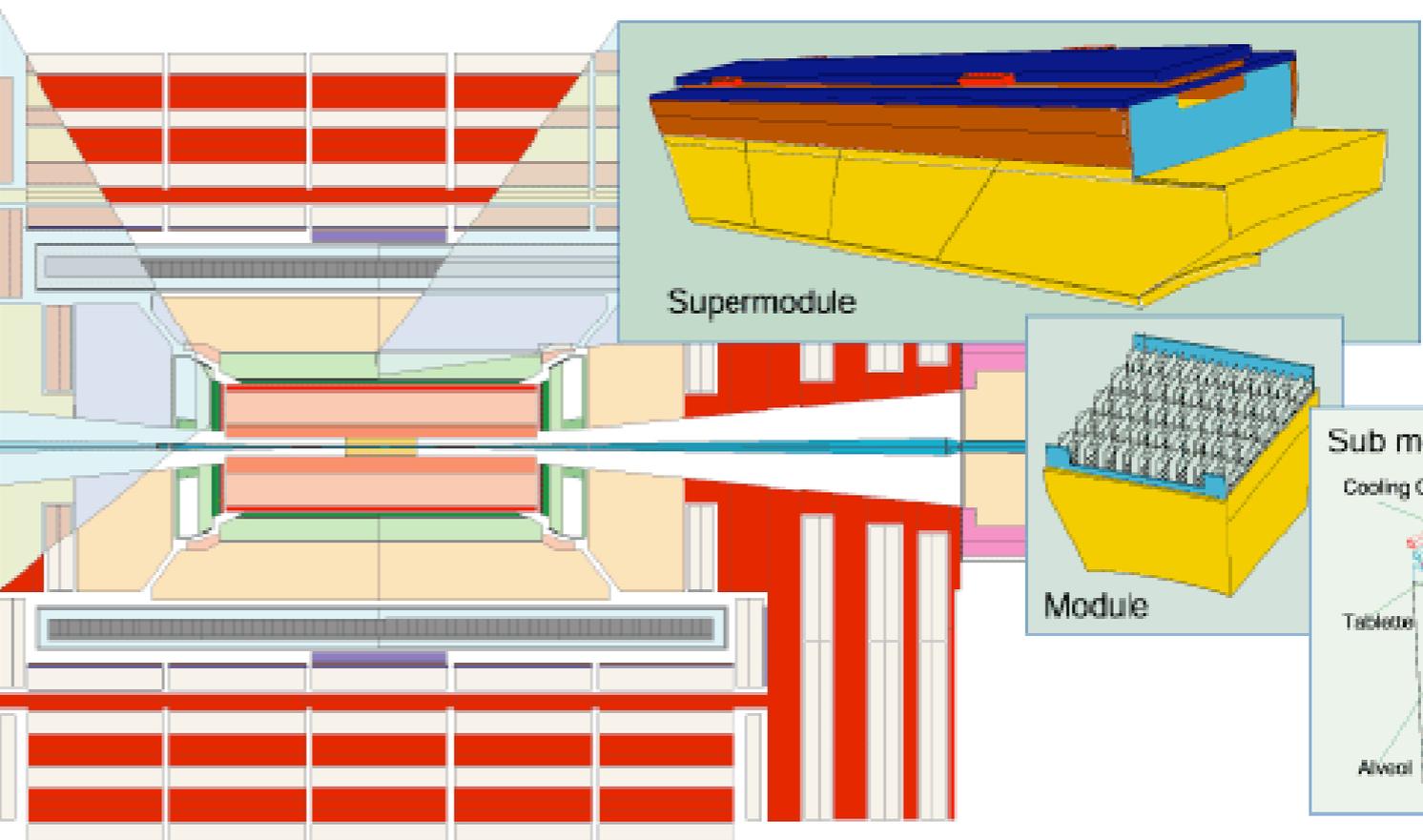
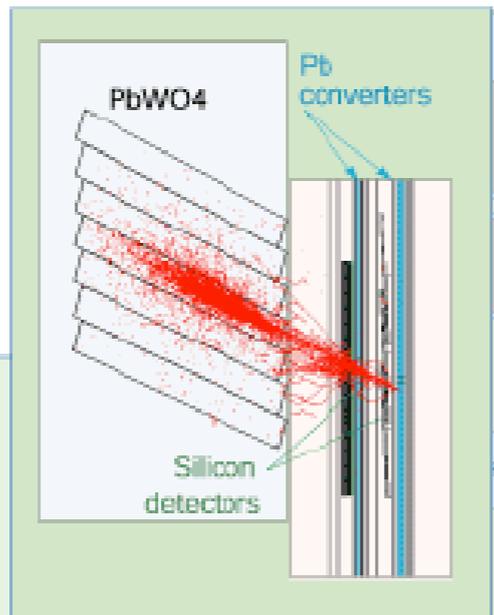
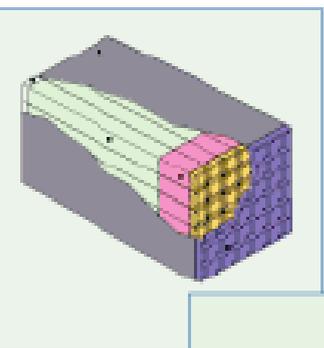
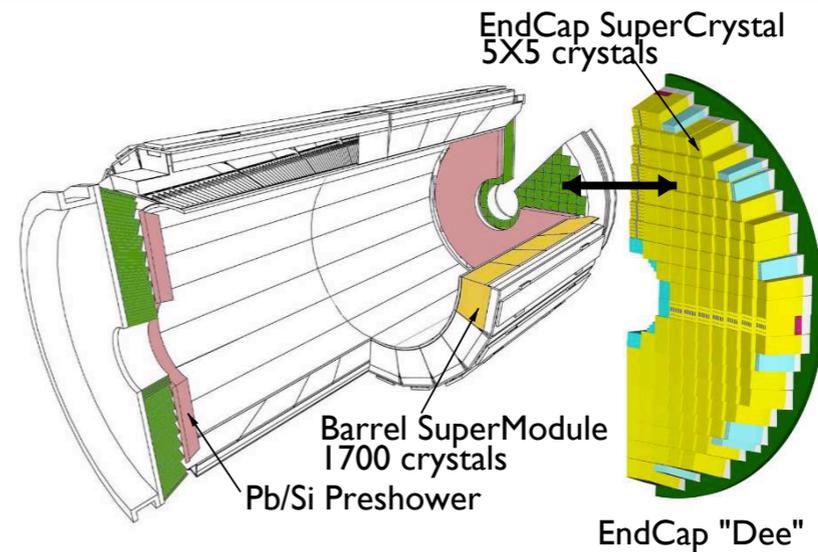


*Alessandro Thea
ETH Zurich
On behalf of the CMS ECAL Group*



ECAL Design and Characteristics

Design benchmark
 $H \rightarrow \gamma\gamma$ ($M_H < 140 \text{ GeV}/c^2$)
 Target resolution
 $\Delta E/E \sim 0.5\%$ for $E > 100 \text{ GeV}$



EndCap: $1.48 < |\eta| < 3.0$
 4 Dees: 14648 crystals ($3 \times 3 \times 22 \text{ cm}^3$)
 with a Pb ($3X_0$)-Si Strip Preshower

$\sim 10\text{m}^2, 90 \text{ tons}$

Barrel: $|\eta| < 1.48$
 36 SuperModules
 61200 crystals ($2.2 \times 2.2 \times 23 \text{ cm}^3$)

Every 25 nsec: 20 events, 1000 tracks (high luminosity)

→ Fast, high granularity, triggering capability

High radiation levels: direct from collisions

→ ECAL Barrel: ≤ 0.3 Gy/h (x 10-50 Endcaps)

Strong magnetic field: 3.8 Tesla

ECAL detector is barely or practically unserviceable



High reliability + On-detector signal processing

PbWO₄

Homogeneous medium

Fast light emission ~80% in 25 ns

Short radiation length $X_0 = 0.89$ cm

Small Molière radius $R_M = 2.10$ cm

Emission peak 425nm

Reasonable radiation resistance
to very high doses

Caveats

LY temperature dependence $-2.2\%/^{\circ}\text{C}$

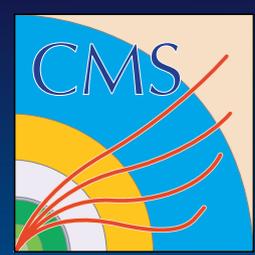
Stabilize to $\leq 0.1^{\circ}\text{C}$ → need cooling

Formation/decay of color centers →

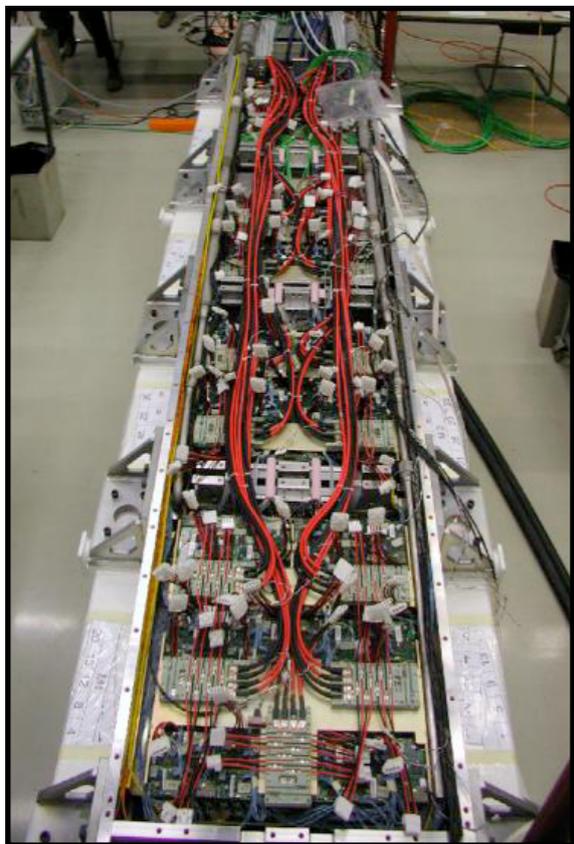
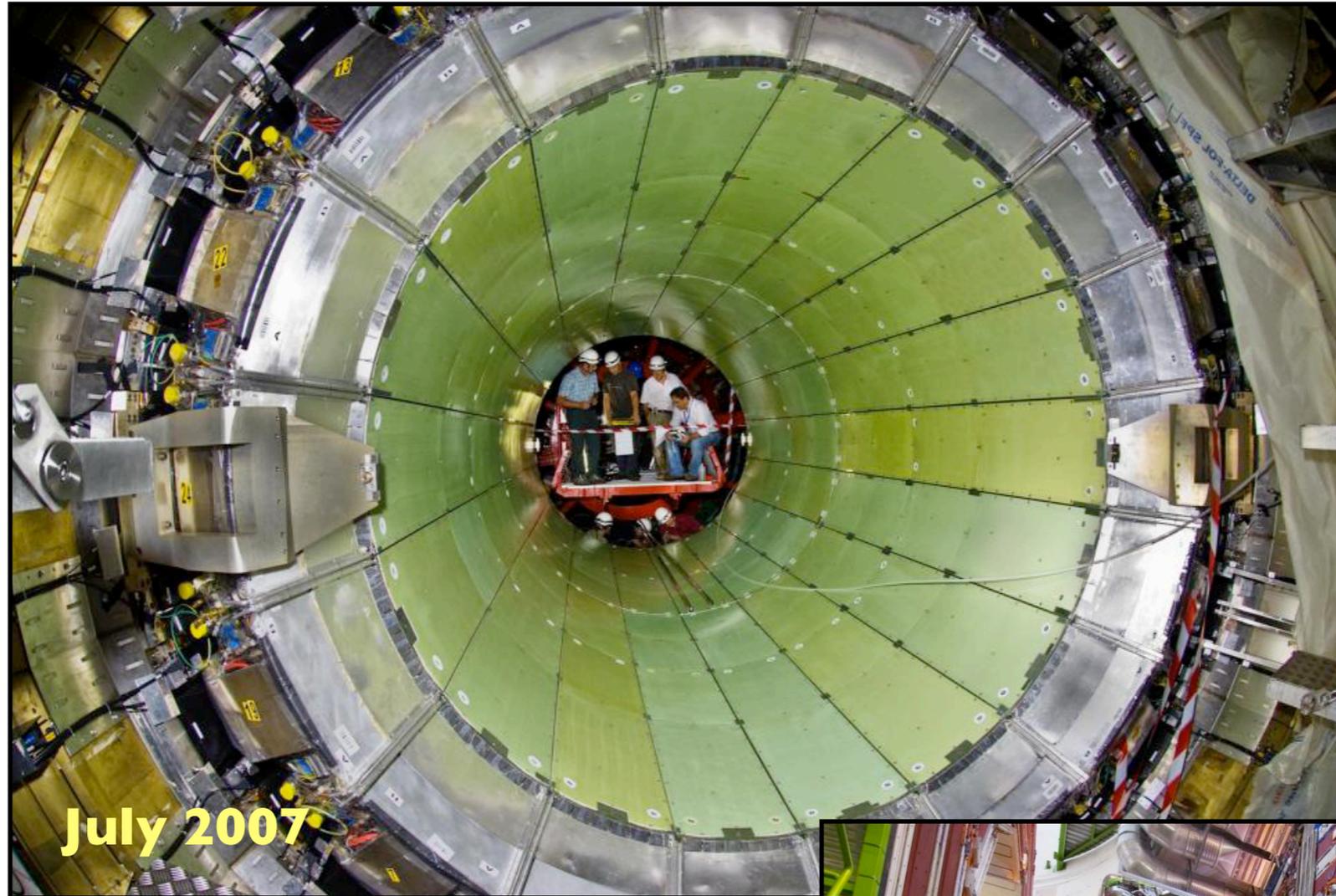
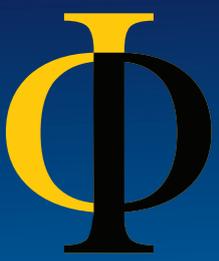
Need precise light monitoring system

Low light yield (100 γ /MeV) →

Need photodetectors with gain

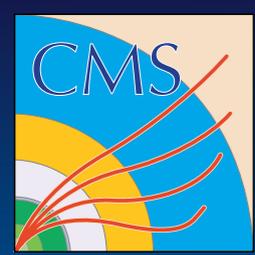


ECAL: The Barrel

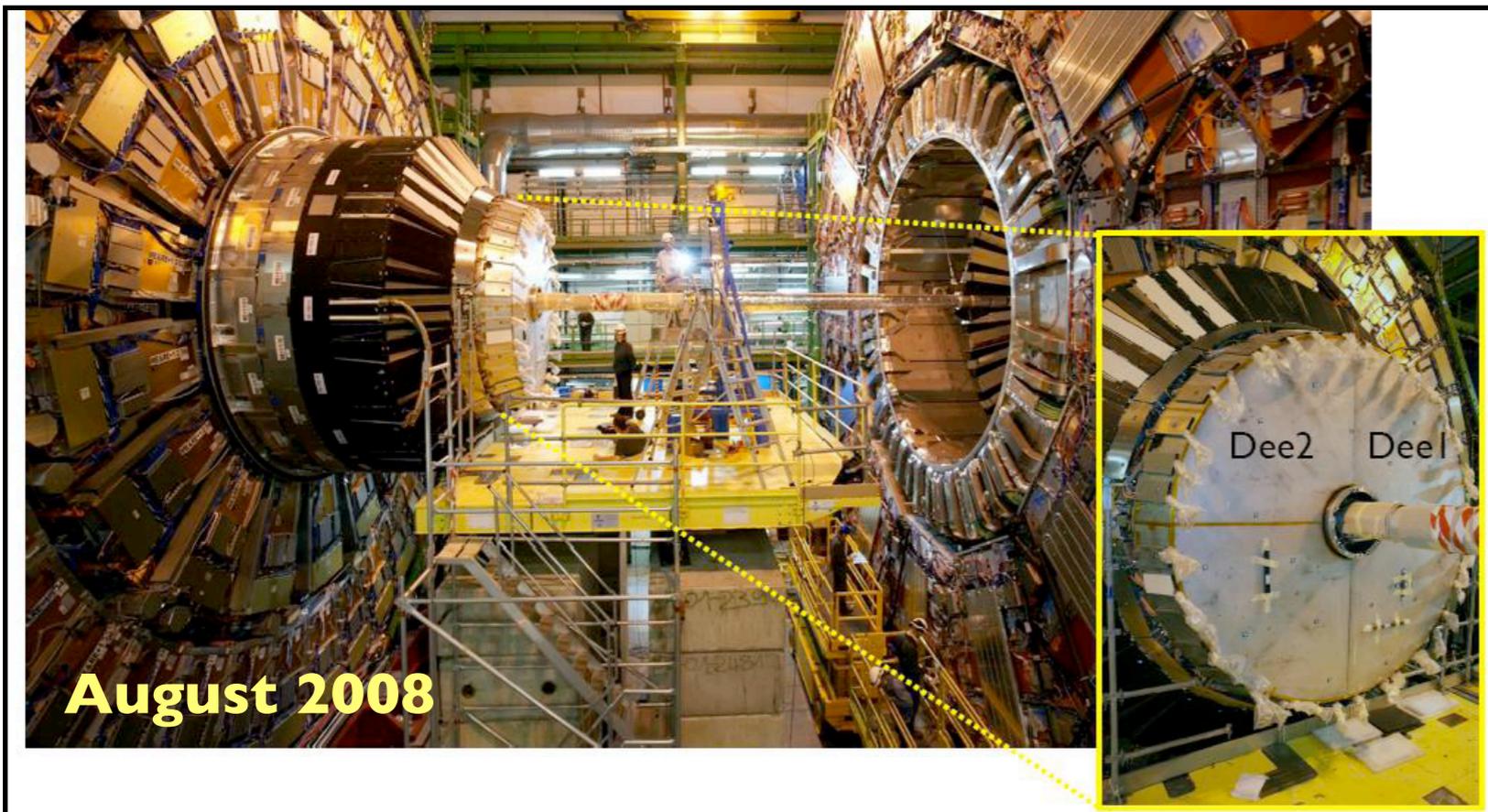
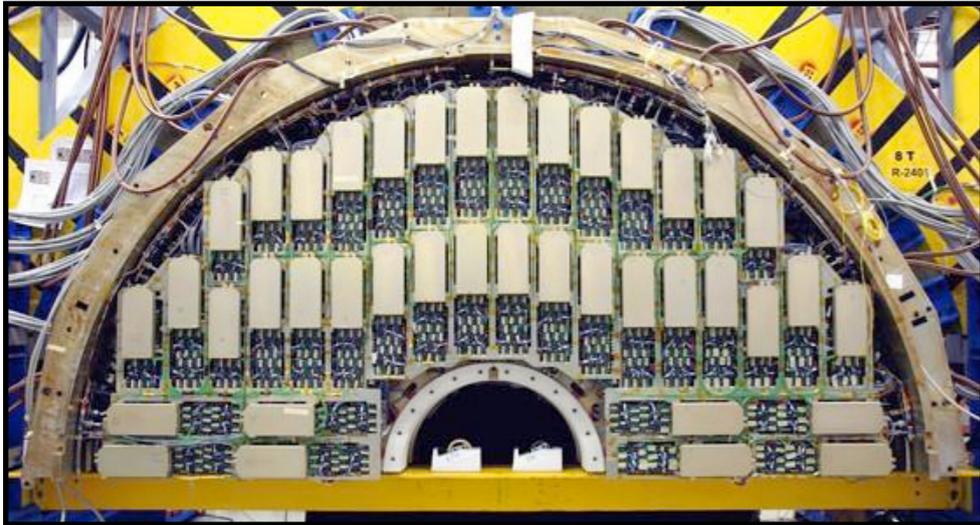


erence

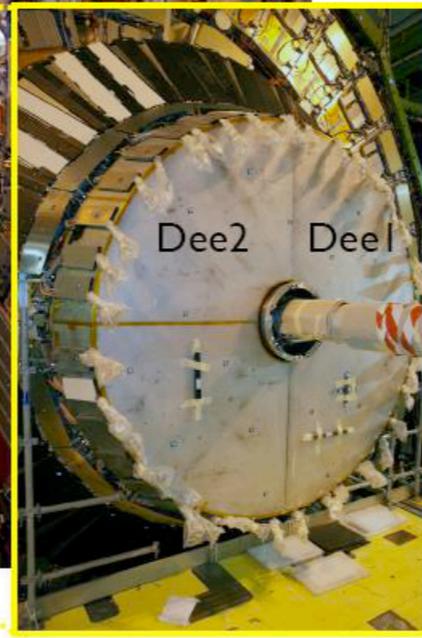
Alessandro Thea - ETH



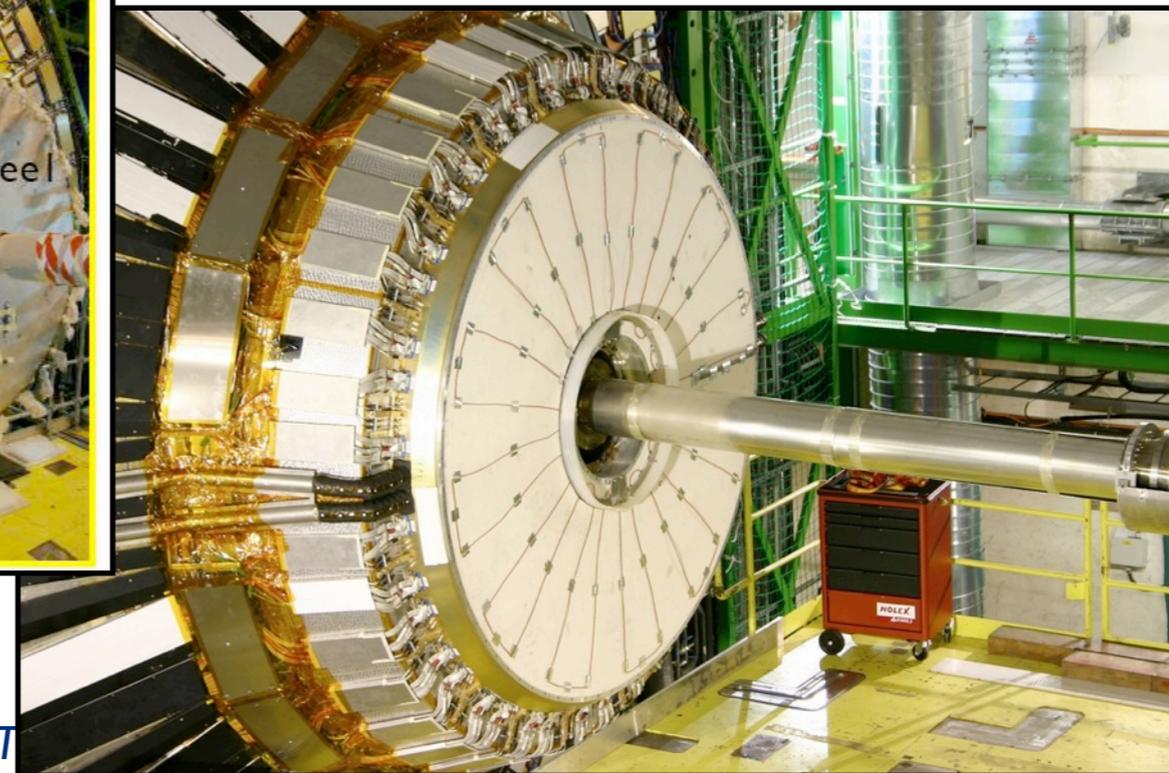
ECAL: The Endcaps

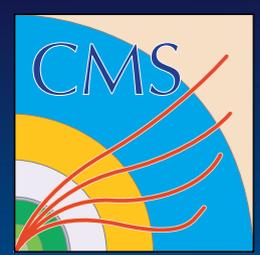


August 2008

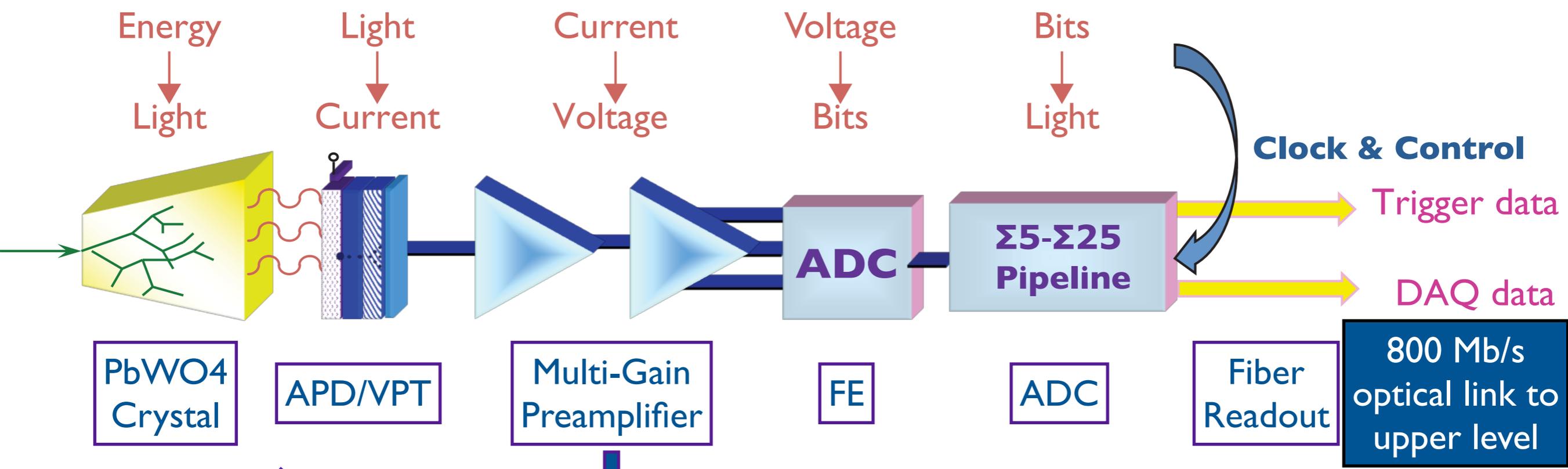
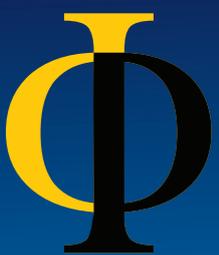


**Pb/Si Preshower
Installed during the
'09 winter shutdown**



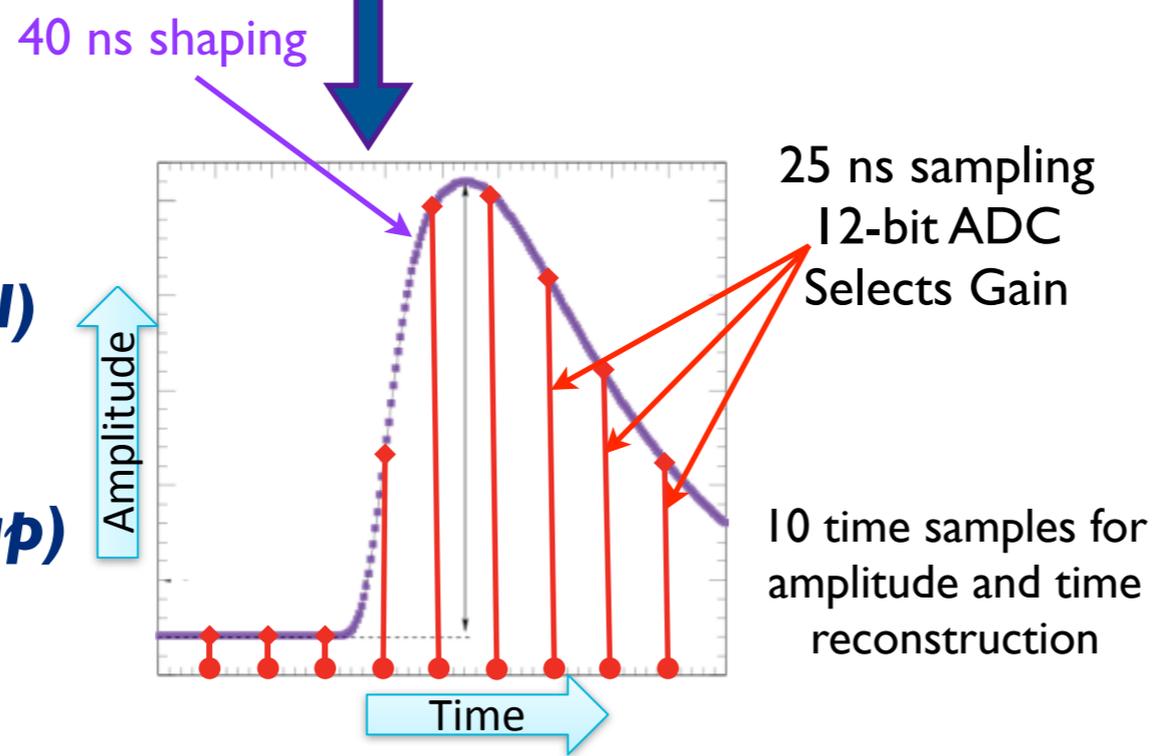
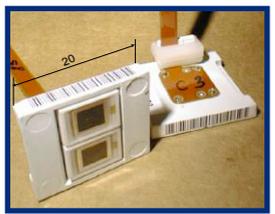


Front-end readout chain



APT (Barrel)
Gain 50/200

VPT (Endcap)
Gain 8-10



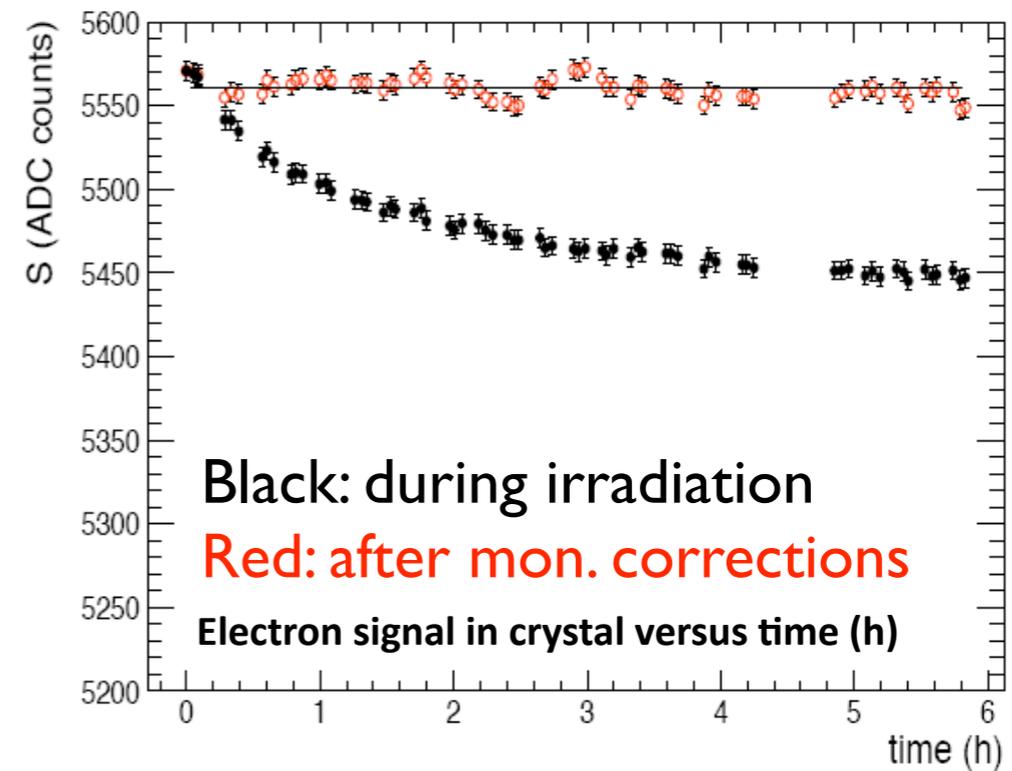
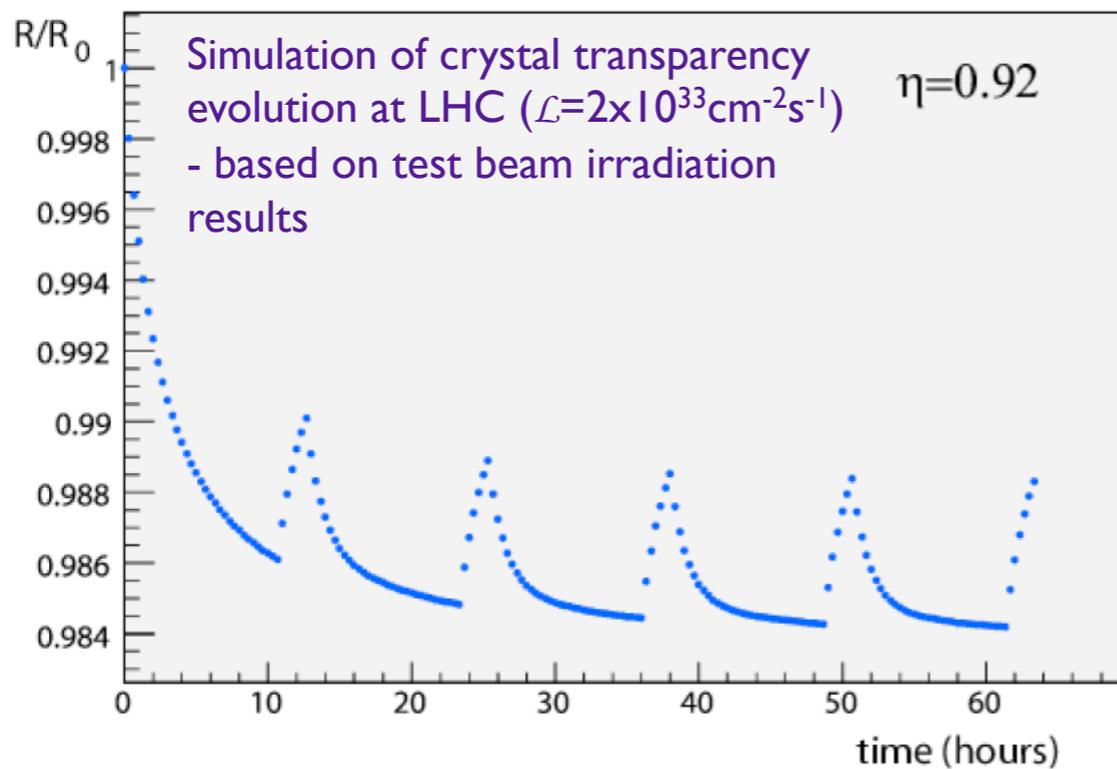
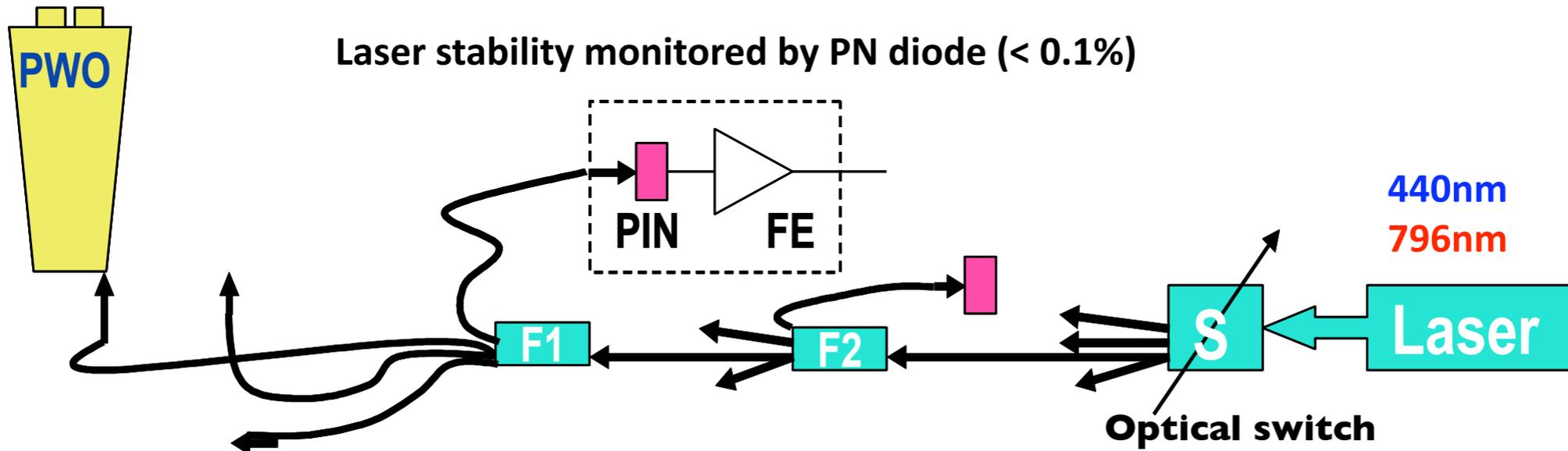
Data integrity checks
Event formatting

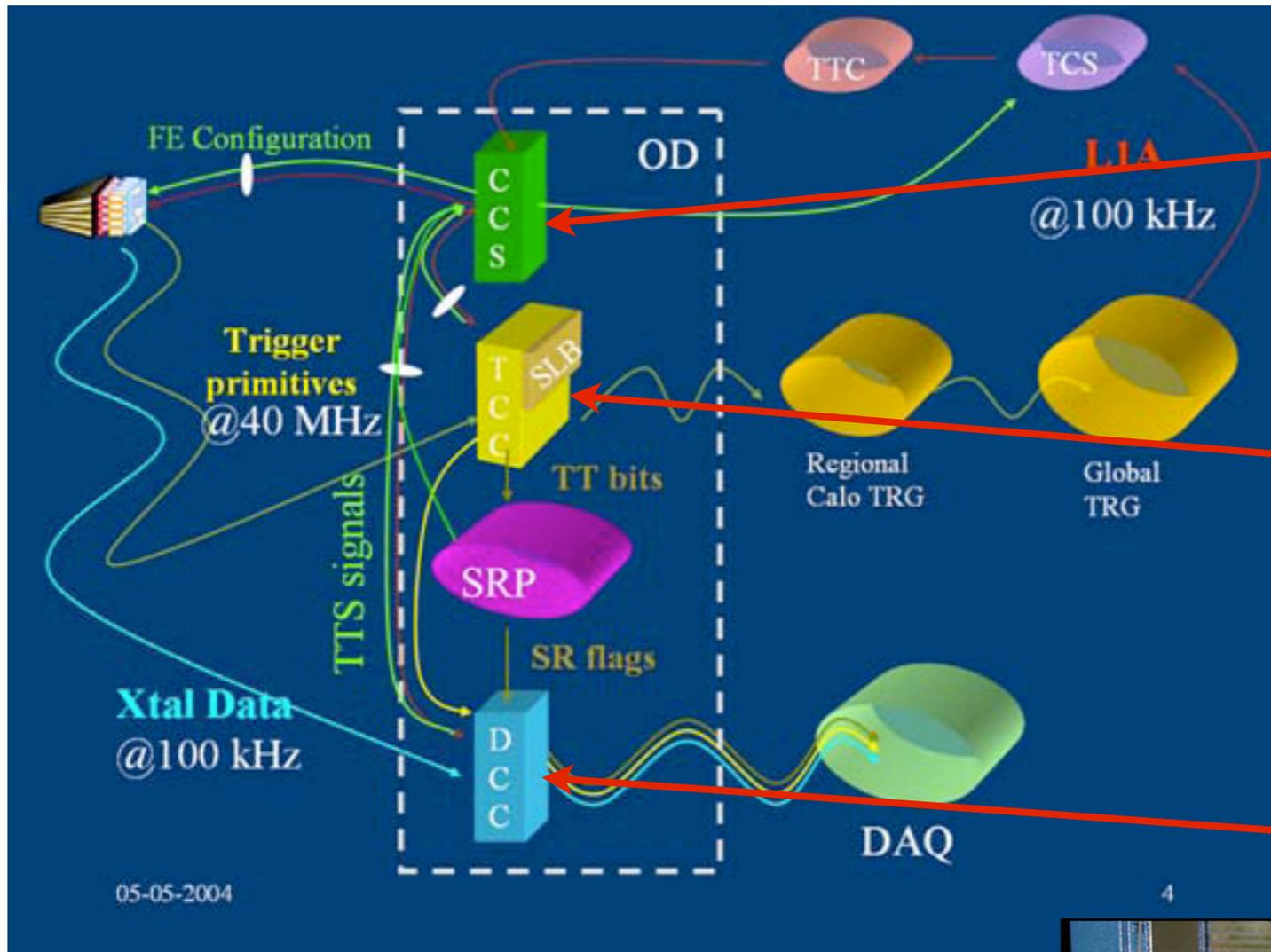
- Bandwidth to DAQ:
- Maximum 528 Mb/s

Average 200 Mb/s
Data Reduction:

- Selective readout
- Zero suppression

Suppression factor ~20





TCC
Control



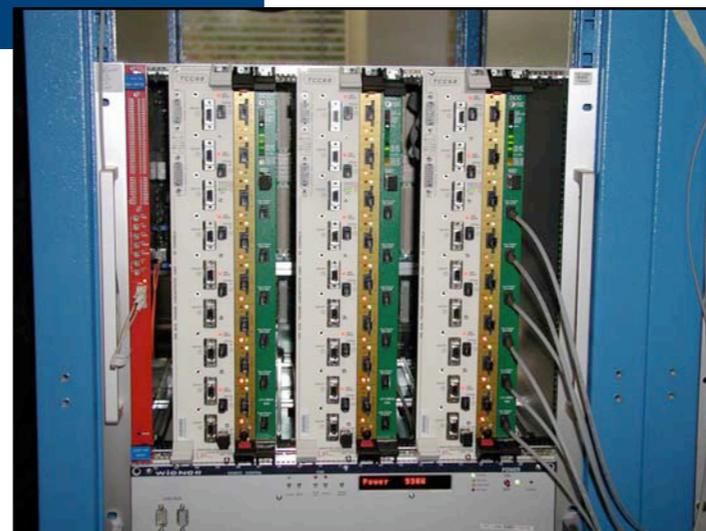
TCC
Trigger



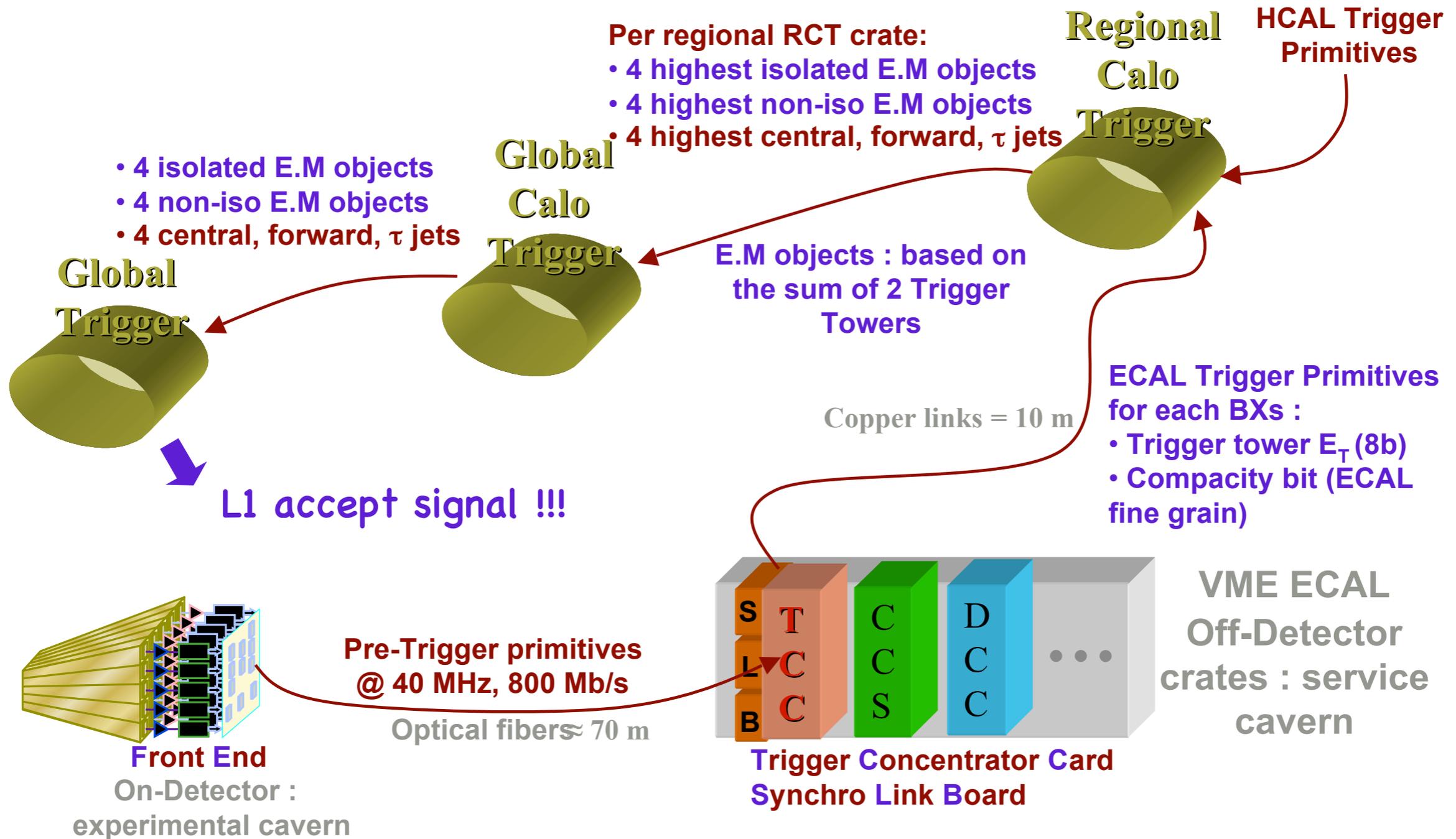
DCC
Data

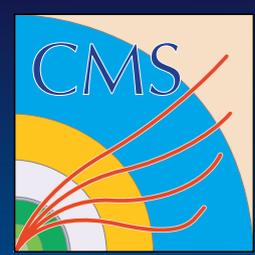


Barrel 1 TCC68 per SM
Endcap 4 TCC per sector

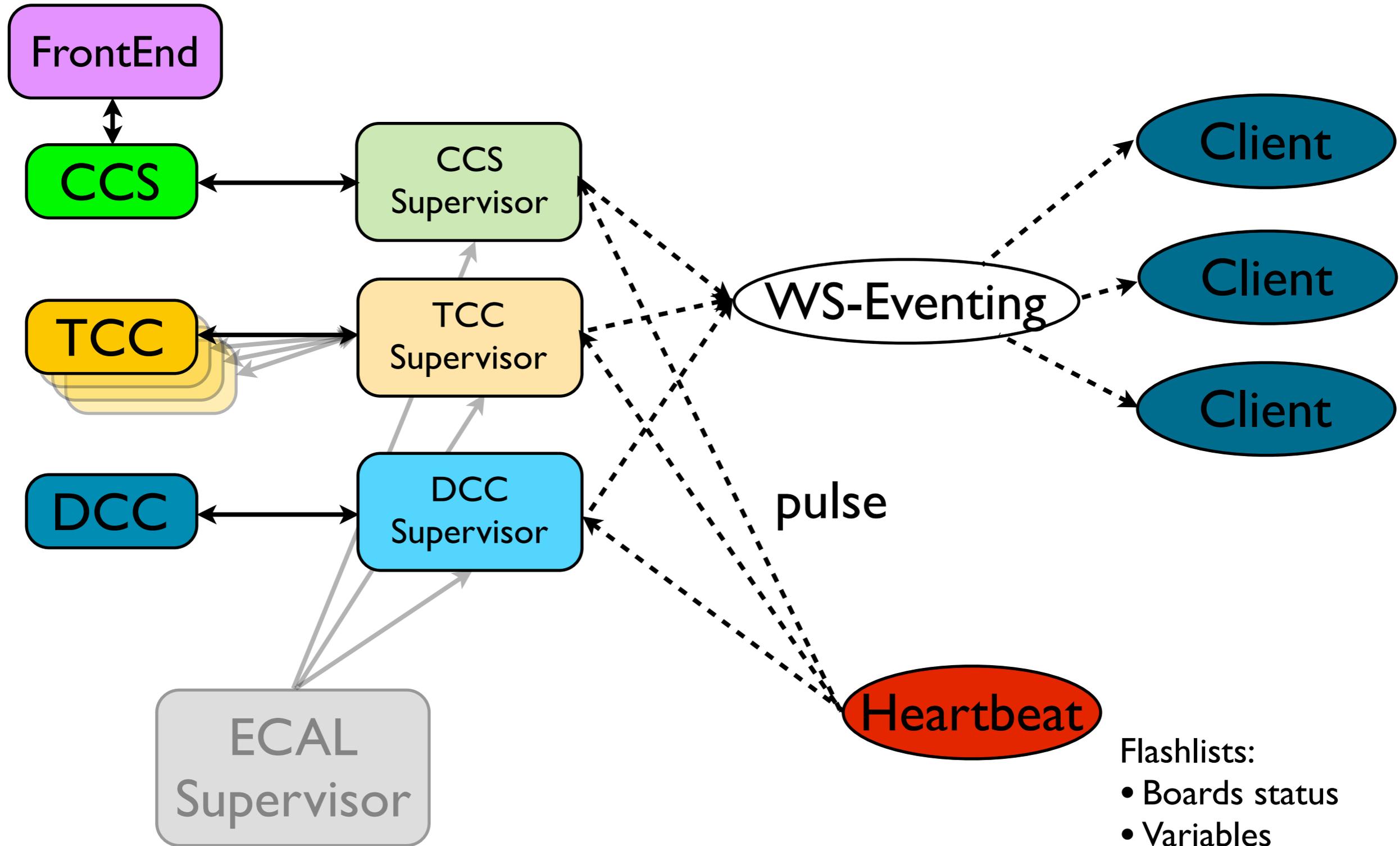


Barrel VME Crate
 3x [DCC, TCC, CCS]

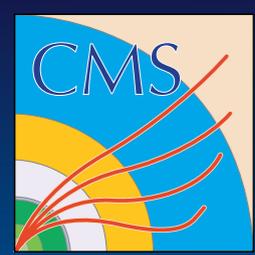




OD Monitoring



- Flashlists:
- Boards status
 - Variables
 - Tables



Monitoring Clients



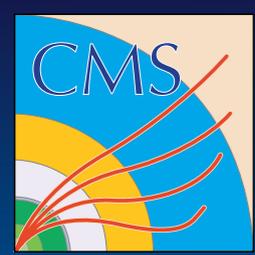
ECALODMonitorin... TriDAS/ecal/ecal... XMAS Tree CVS-Concurrent... University of Notr... TextFormattingRu...

XMAS Tree - Vimperator

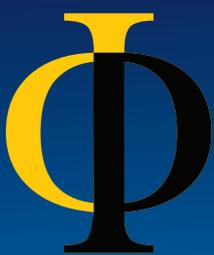
CMS ECAL OD Electronics Monitor: XMAS Tree

Monitoring clients		FED	FE	CCS	TCC	SRP	DCC	FEDs				
DCC monitor		601	EE-7	OK	OK	-	-	READY DAQ	LIA: 70 BX: 3376 Info	601	602	603
CCS monitor		602	EE-8	OK	OK	-	-	READY DAQ	LIA: 74 BX: 3376 Info	EE-7	EE-8	EE-9
TCC monitor		603	EE-9	OK	OK	-	-	READY DAQ	LIA: 66 BX: 3376 Info	604	605	606
SRP monitor		604	EE-1	OK	OK	-	-	READY DAQ	LIA: 69 BX: 3376 Info	EE-1	EE-2	EE-3
XMAS Tree		605	EE-2	OK	OK	-	-	READY DAQ	LIA: 50 BX: 3397 Info	607	608	609
TPG histograms		606	EE-3	OK	OK	-	-	READY DAQ	LIA: 67 BX: 3376 Info	EE-4	EE-5	EE-6
Trigger monitor		607	EE-4	OK	OK	-	-	READY DAQ	LIA: 71 BX: 3376 Info	610	611	612
QPLL monitor		608	EE-5	32: Tower not accessible	OK	-	-	READY DAQ	LIA: 76 BX: 3376 Info	EB-1	EB-2	EB-3
Alarm handler		609	EE-6	OK	OK	-	-	READY DAQ	LIA: 67 BX: 3376 Info	613	614	615
XMAS pulser		610	EB-1	OK	OK	TCC 37 OK	-	READY DAQ	LIA: 11674655 BX: 2273 Info	EB-4	EB-5	EB-6
XMAS dashboard		611	EB-2	13: QPLL is not locked	OK	TCC 38 OK	-	READY DAQ	LIA: 11674732 BX: 1051 Info	616	617	618
Help		612	EB-3	OK	OK	TCC 39 OK	-	READY DAQ	LIA: 11674785 BX: 2211 Info	EB-7	EB-8	EB-9
										619	620	621
										EB-10	EB-11	EB-12
										622	623	624
										EB-13	EB-14	EB-15
										625	626	627
										EB-16	EB-17	EB-18
										628	629	630
										EB+1	EB+2	EB+3
										631	632	633
										EB+4	EB+5	EB+6
										634	635	636
										EB+7	EB+8	EB+9
										637	638	639
										EB+10	EB+11	EB+12
										640	641	642
										EB+13	EB+14	EB+15
										643	644	645
										EB+16	EB+17	EB+18
										646	647	648
										EE+7	EE+8	EE+9
										649	650	651
										EE+1	EE+2	EE+3
										652	653	654
										EE+4	EE+5	EE+6

http://ecalod-xmas.cms:9810/urn:rdag-application:110-50 [+] [3/4] Top



DCC monitor



CMS ECAL OD Electronics Monitor: DCC status

Monitoring DCC status [Refresh]

601 EE-7 DAQ READY	602 EE-8 DAQ READY	603 EE-9 DAQ READY	604 EE-1 DAQ READY	605 EE-2 DAQ READY	606 EE-3 DAQ READY	607 EE-4 DAQ READY	608 EE-5 DAQ READY	609 EE-6 DAQ READY
610 EB-1 DAQ READY	611 EB-2 DAQ READY	612 EB-3 DAQ READY	613 EB-4 DAQ READY	614 EB-5 DAQ READY	615 EB-6 DAQ READY	616 EB-7 DAQ READY		
619 EB-10 DAQ READY	620 EB-11 DAQ READY	621 EB-12 DAQ READY	622 EB-13 DAQ READY	623 EB-14 DAQ READY	624 EB-15 DAQ READY	625 EB-16 DAQ READY		
628 EB+1 DAQ READY	629 EB+2 DAQ READY	630 EB+3 DAQ READY	631 EB+4 DAQ READY	632 EB+5 DAQ READY	633 EB+6 DAQ READY			

DCC status [Clear data]

Boards		
601	602	603
EE-7	EE-8	EE-9
604	605	606
EE-1	EE-2	EE-3
607	608	609

CMS ECAL OD Electronics Monitor: DCC status

Monitoring DCC status [Refresh]

633 (EB+6) : READY

Time of last update: Fri Aug 22 14:27:45 2008

Back size: 88	Bunch nb: 88
Channel id: 10	Data timeout: 70
Event nb: 58	FIFO almost full: AF
FIFO full: FF	Header: BA
Hor. parity: 3p	Vert. parity: Vp
Link: Ln	

BOARD STATUS TABLE

Global TTS Status:	READY
--------------------	-------

Info:

```

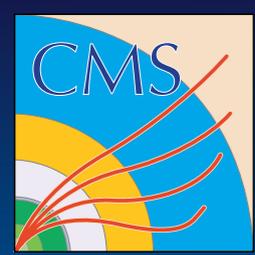
----- DCC STATUS INFO -----
- OPERATION REE (DELINKING) : RUNNING
- LIA DATA WAITING : YES
- DAQ LINK STATUS : READY
- SPY DATA PRESENT : NO
- DT TTS STATUS : READY
- SLINK FIFOFULL FLAG : NO
- CLINKDOWN FLAG : NO
- VME MEMORY : NOT OVERFLOW
- GLOBAL TTS STATUS : READY
- DCC ERROR MULTI : NO

- Rate: 4440/1000000
- Back pressure counter: 0
- N LIA waiting (ORPH): 0
- PED id configured: 633 (0+279)
- JTAC Access mode: VME

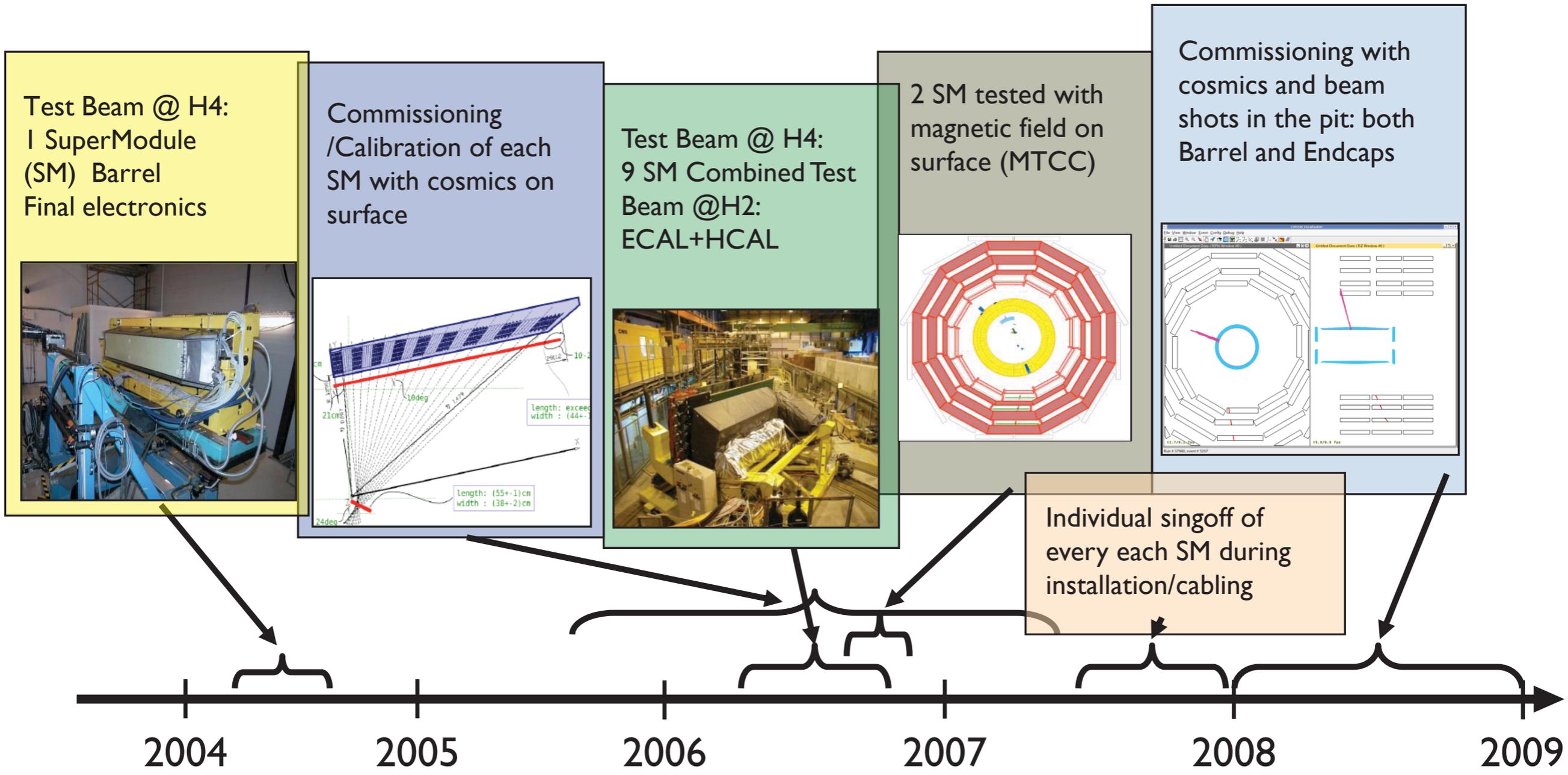
-----
Words in SPP file: 417532
Events in DT170: 1296
Last Bunch triggered: 6049
LIA counter: 664
  
```

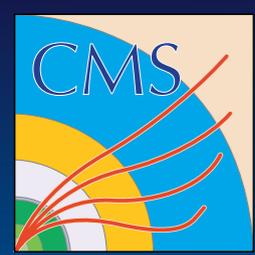
DCC status [Clear data]

Boards		
601	602	603
EE-7	EE-8	EE-9
604	605	606
EE-1	EE-2	EE-3
607	608	609
EE-4	EE-5	EE-6
610	611	612
EB-1	EB-2	EB-3
613	614	615
EB-4	EB-5	EB-6
616	617	618
EB-7	EB-8	EB-9
619	620	621
EB-10	EB-11	EB-12
622	623	624
EB-13	EB-14	EB-15
625	626	627
EB-16	EB-17	EB-18
628	629	630
EB+1	EB+2	EB+3
631	632	633
EB+4	EB+5	EB+6
634	635	636
EB+7	EB+8	EB+9
637	638	639
EB+10	EB+11	EB+12
640	641	642
EB+13	EB+14	EB+15
643	644	645
EB+16	EB+17	EB+18
646	647	648
EE+7	EE+8	EE+9
649	650	651
EE+1	EE+2	EE+3
652	653	654
EE+4	EE+5	EE+6



Commissioning Timeline





Commissioning “Toolbox”

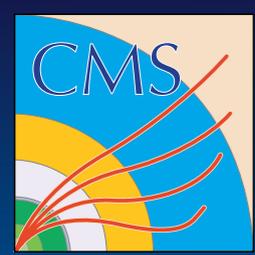


- **Cosmic Events**

- ▶ B field **ON** and **OFF**
- ▶ **Mips** (ECAL triggers using APD gain 200!!!)
- ▶ Catastrophic Bremsstrahlung (up to 200 GeV per event!)

- **LHC first beam Events**

- ▶ 40 hr of beam for CMS
- ▶ **Beam splashes** (spectacular)
- ▶ Halo events (few muons, not really useful)

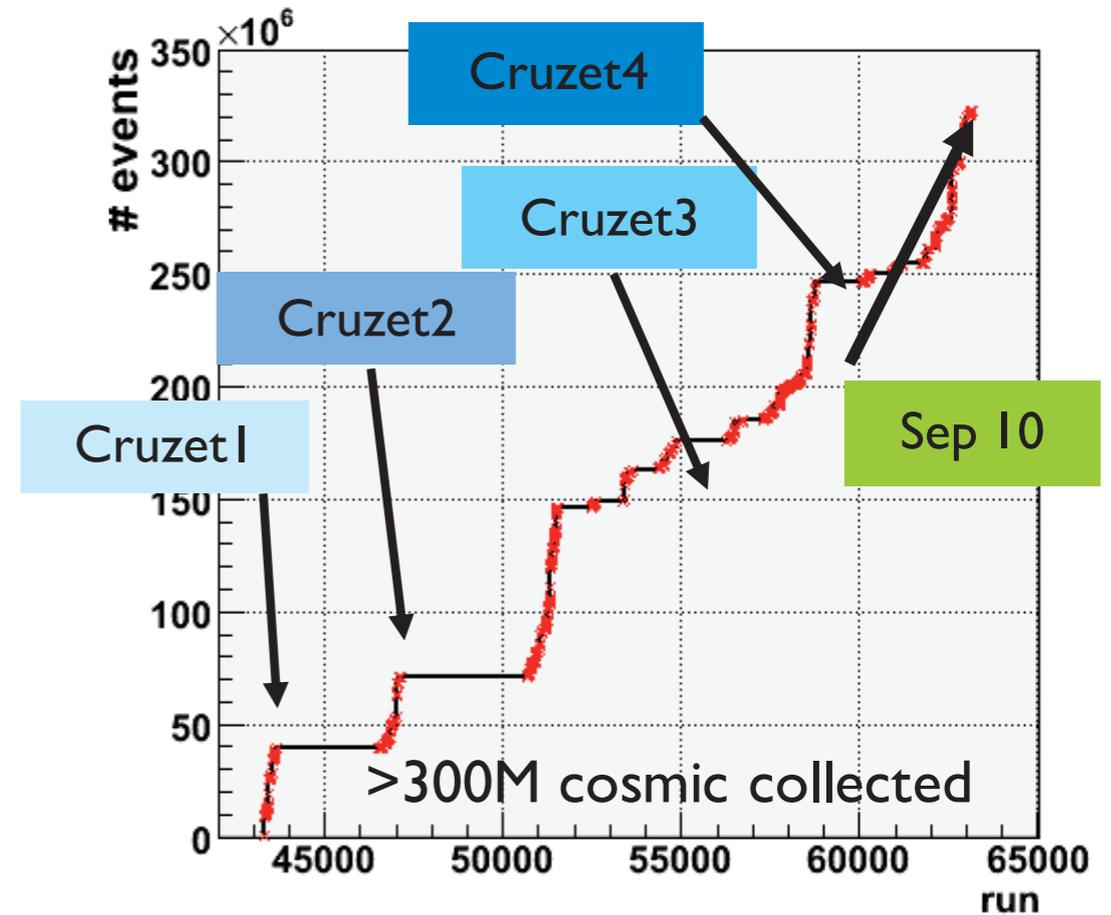
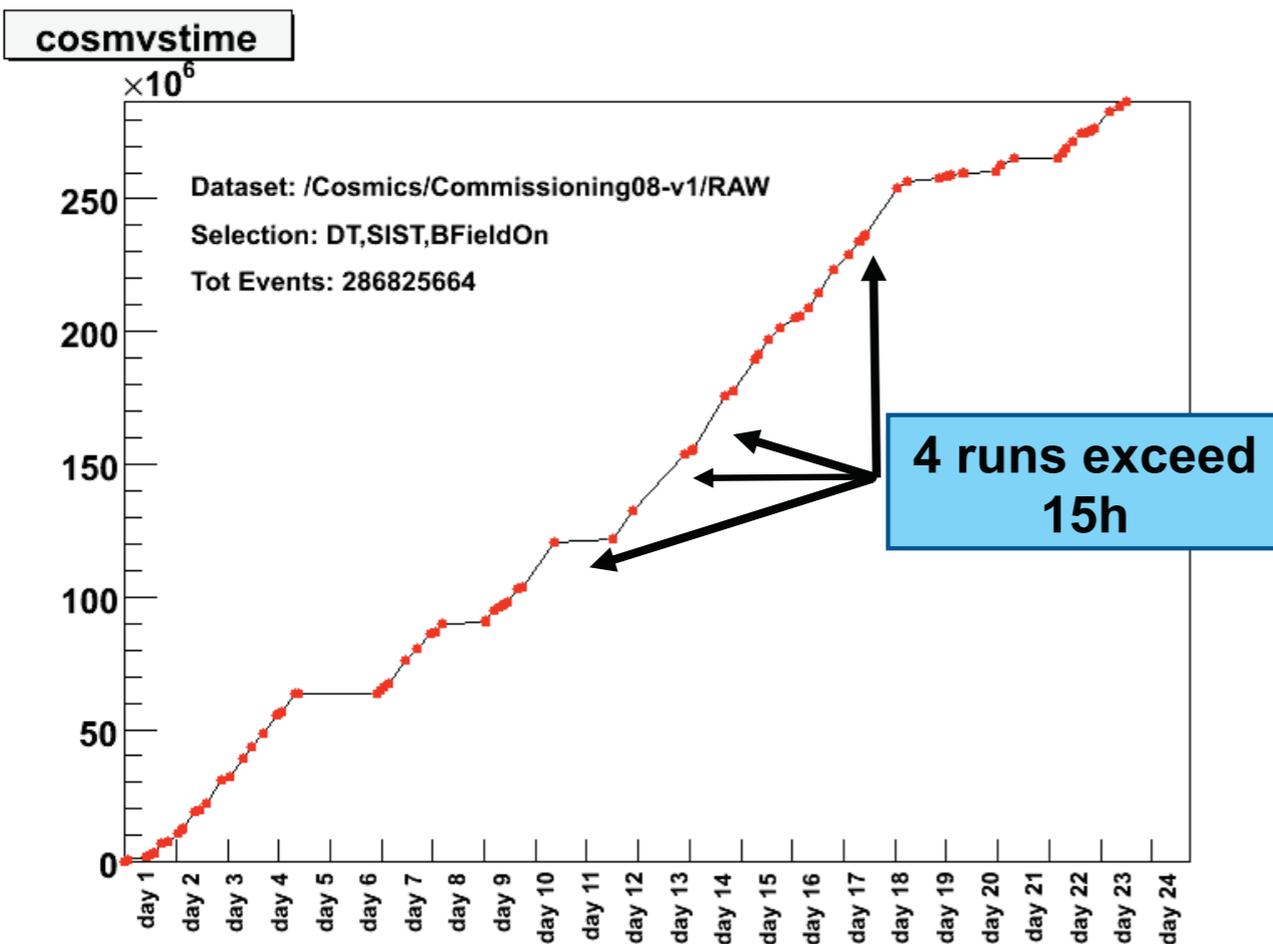


CMS Cosmic Campaign



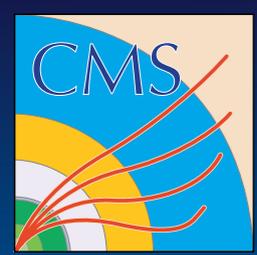
Cosmic RUN at ZERo Tesla

- Several weeks of data taking since May '08
- More than 300M events collected

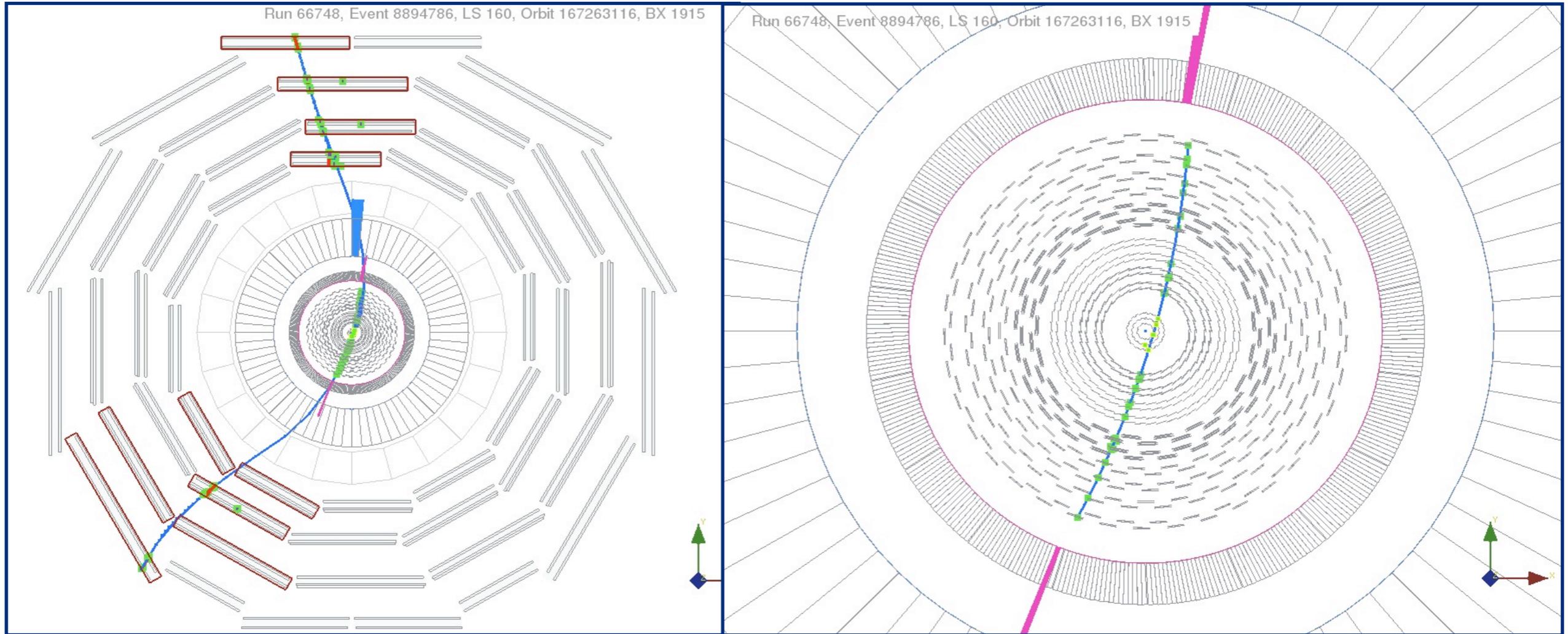
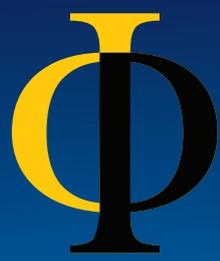


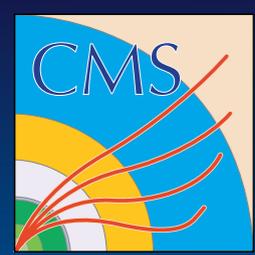
Cosmic Run At Four Tesla

- Continuous running for 4 weeks to gain operational experience
- About 300M events with most of CMS sub-detectors participating
- Magnetic field 3.8T

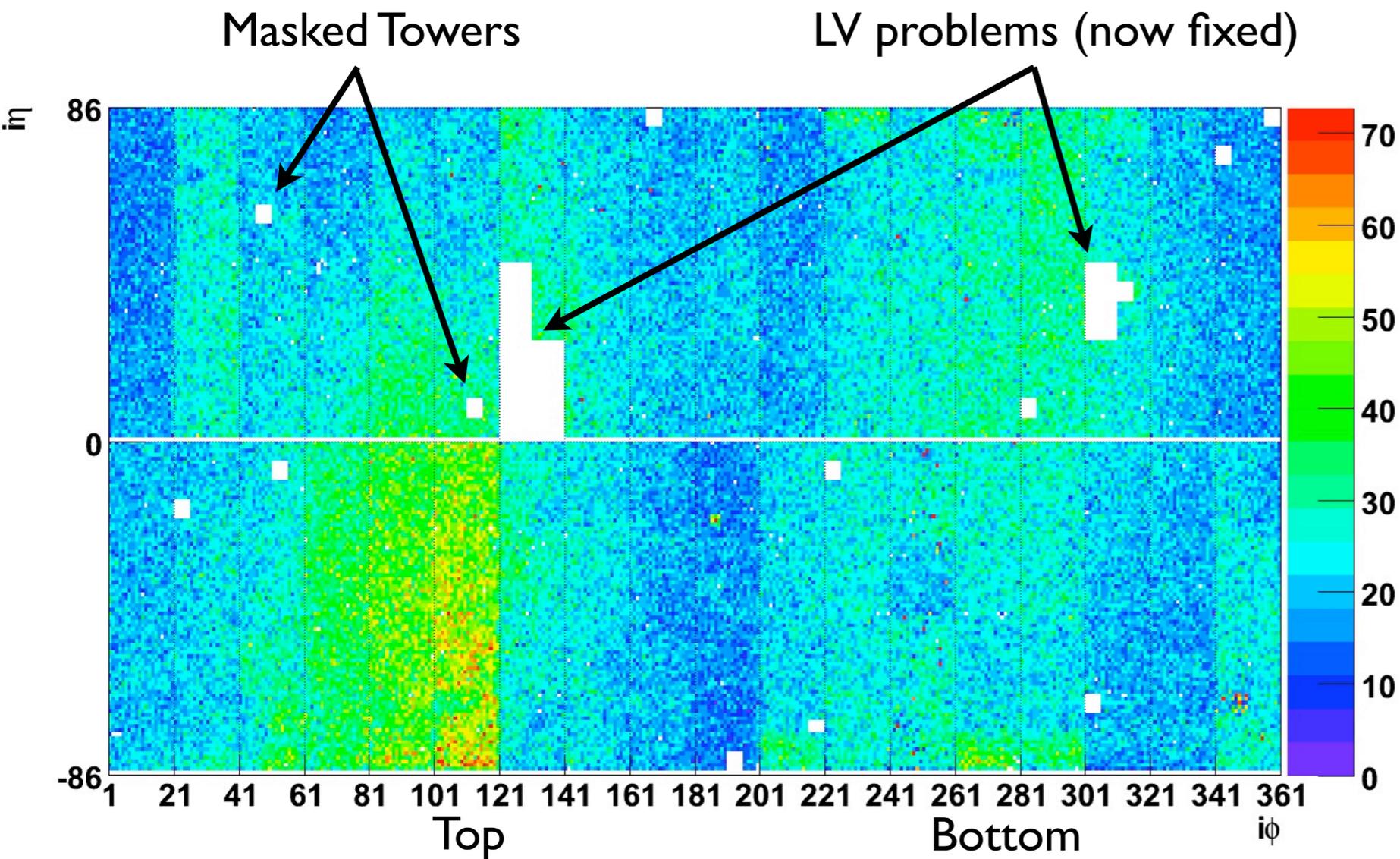


Cosmics: Event Display



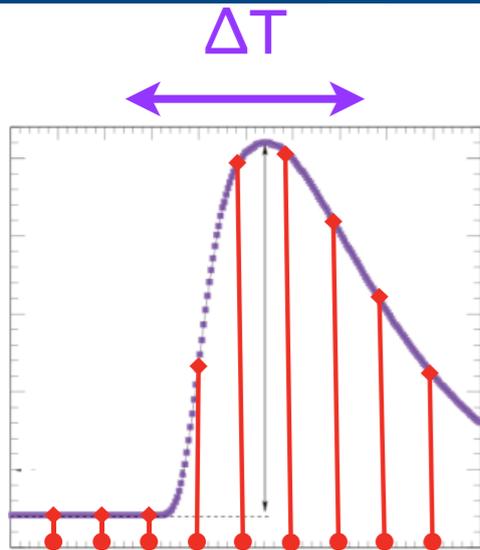


CR: Cluster Occupancy



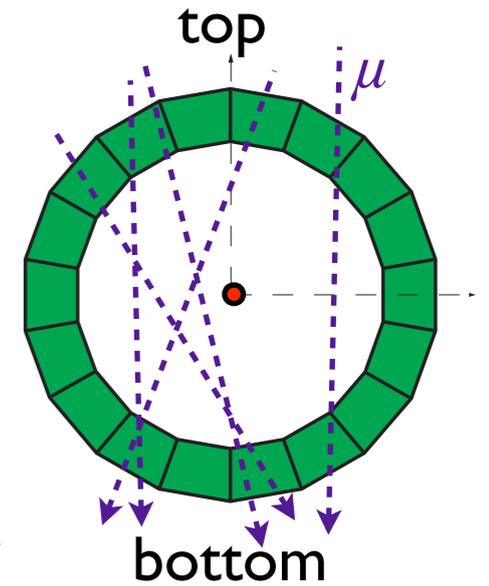
Occupancy

- Top-bottom flux
- Uncalibrated
- Additional modulations due to the cluster efficiency varying with crystal light yield



The ECAL FE uses a set of 10 weights to calculate the pulse amplitude

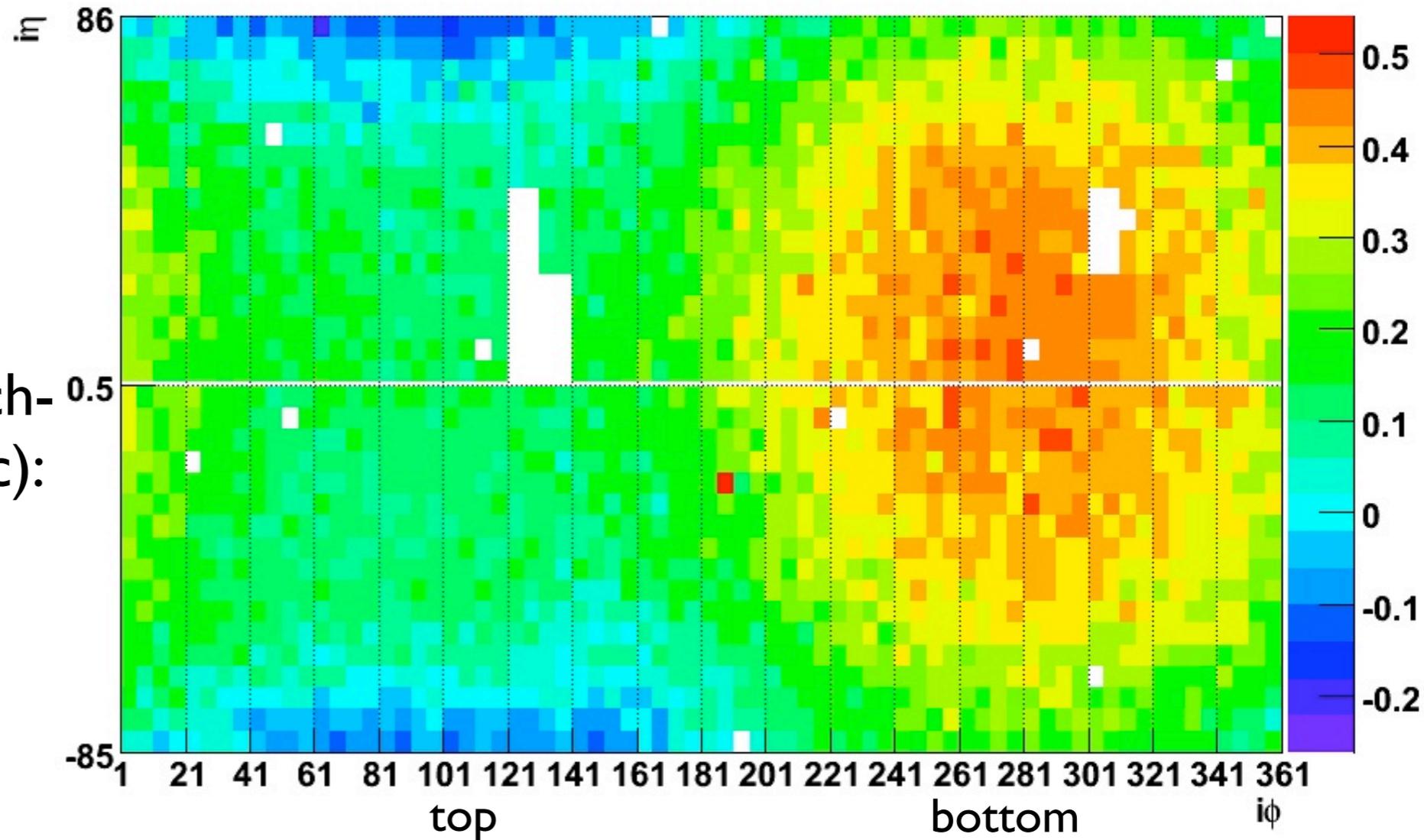
The pulse must be timed in precisely for a correct amplitude reconstruction

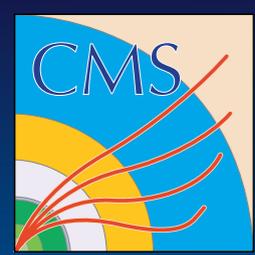


$$t_{top} - t_{bottom} = c \cdot t_{flight}$$

Average timing of a cosmic cluster in bunch-crossing units (25 nsec):

- top-to-bottom
- time of flight



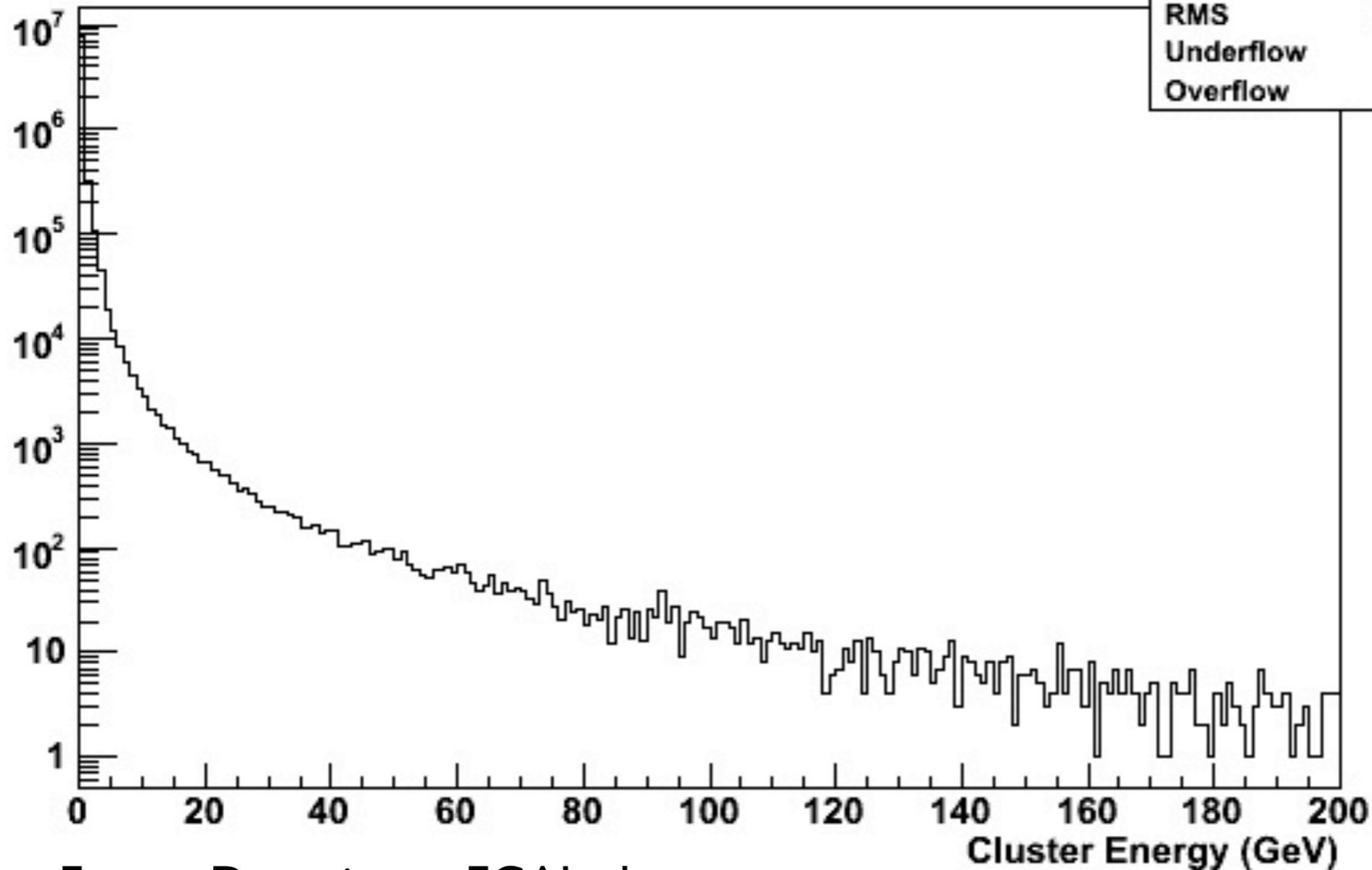


CR: Energy deposit

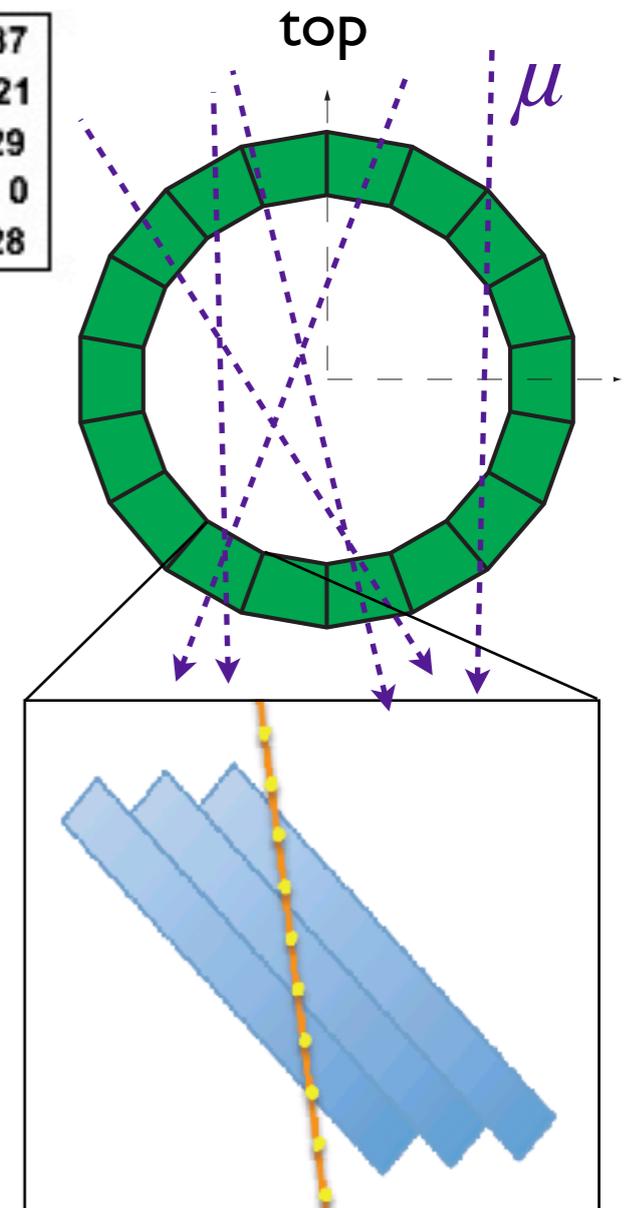


energyHigh_AllClusters, run 200

Entries	8411987
Mean	0.5021
RMS	2.029
Underflow	0
Overflow	328



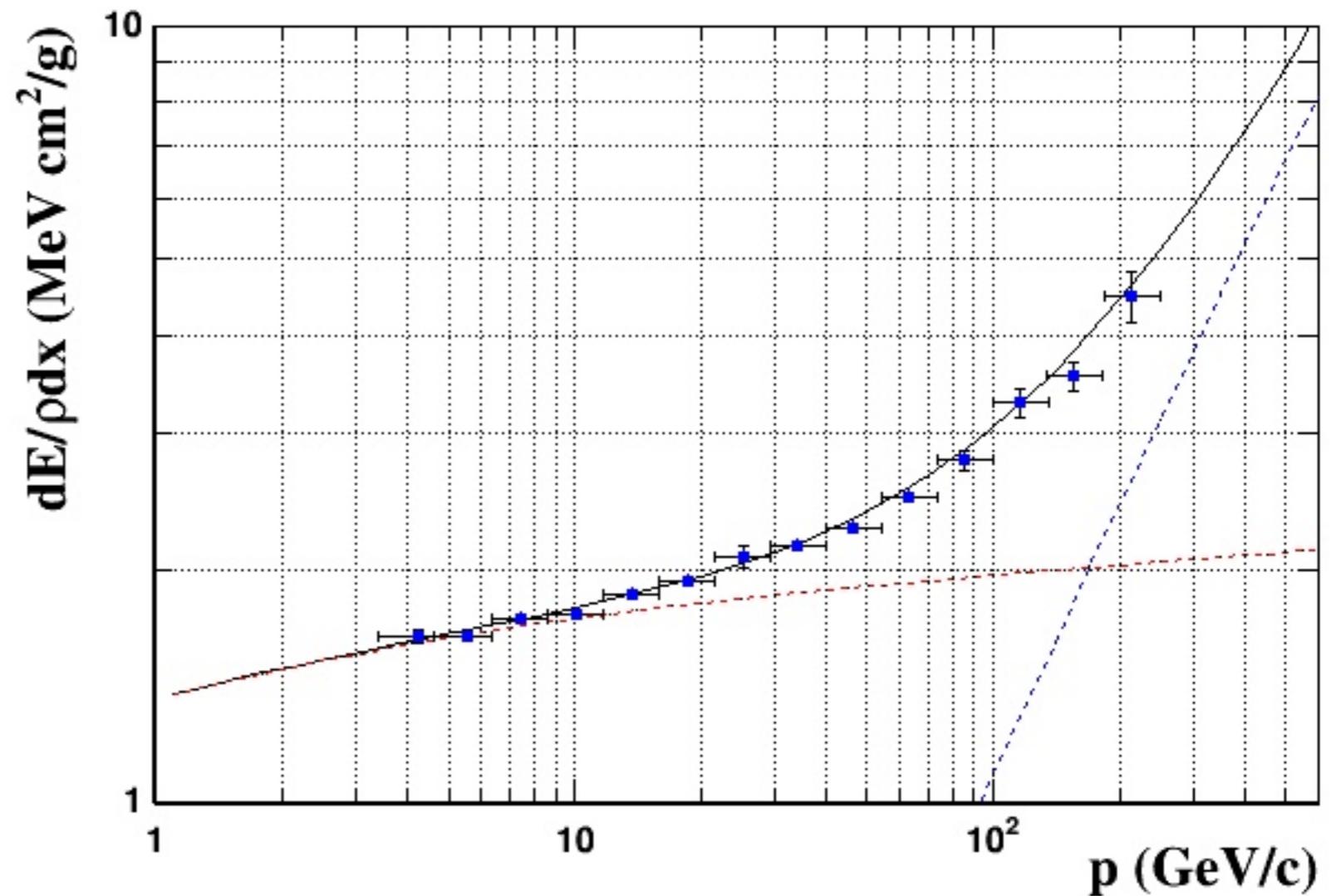
Energy Deposit per ECAL cluster



Dependent on the track path inside the active ECAL volume

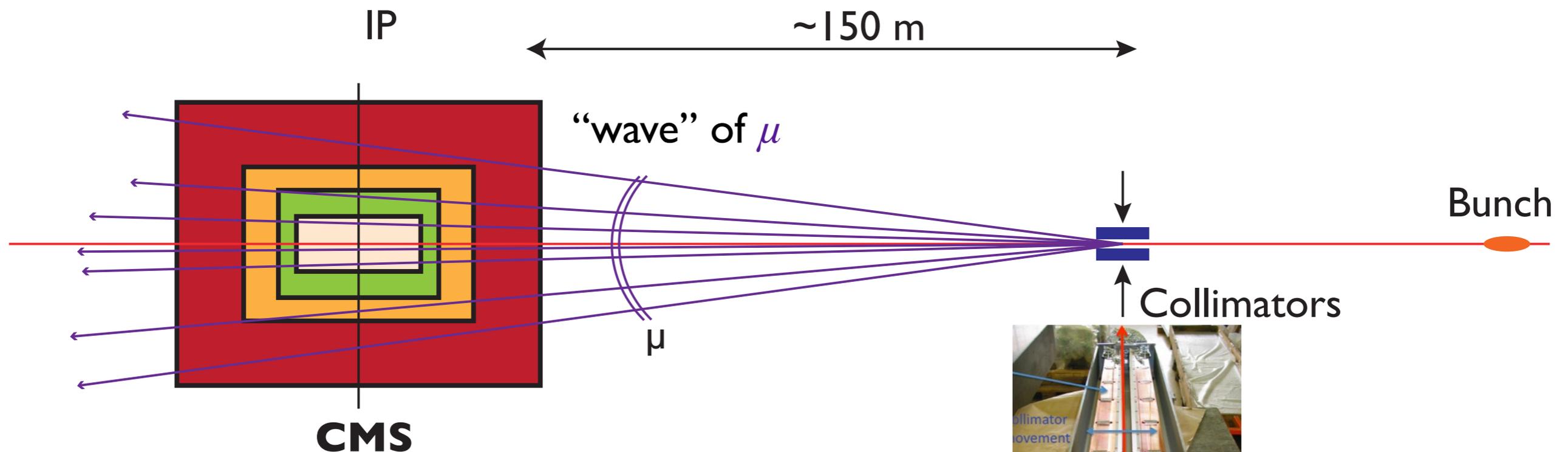
$dE/\rho dx$ of cosmic muons inside ECAL active volume v.s. muon momentum as measured in the tracker

- ECAL measurements
- Bremsstrahlung contribution
- Collision losses
- Total stopping power (not a fit)



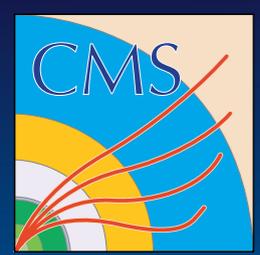
Lhc beam shots

$\sim 2 \times 10^9$ protons hits onto the closed collimator 150 m upstream of CMS

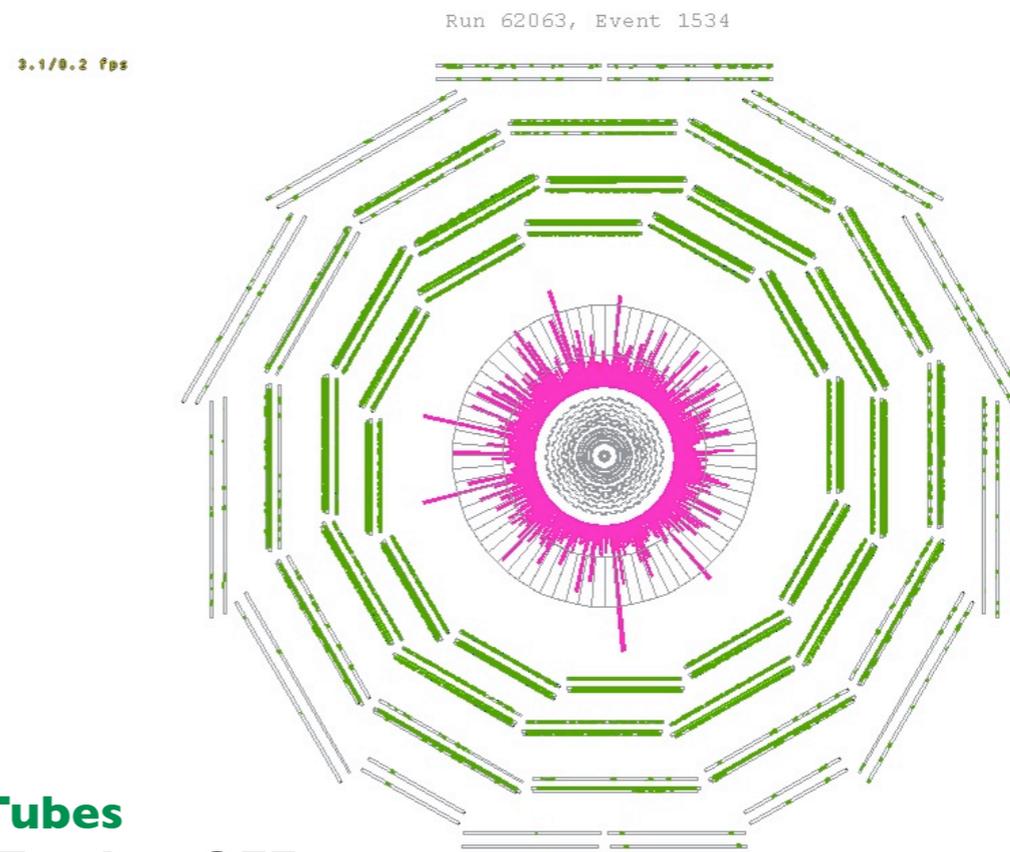
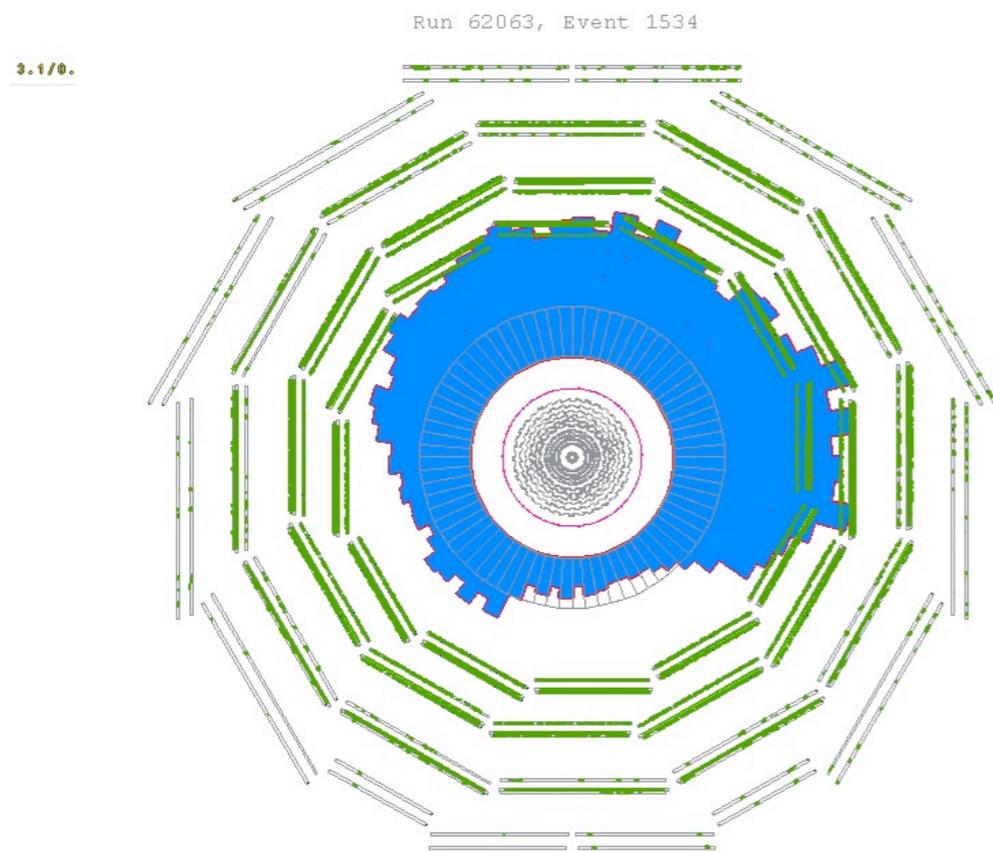
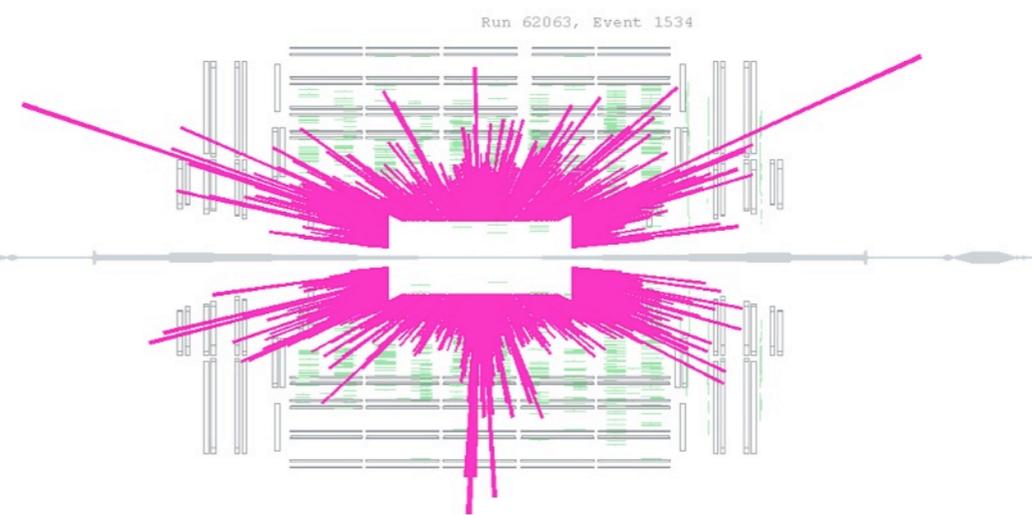
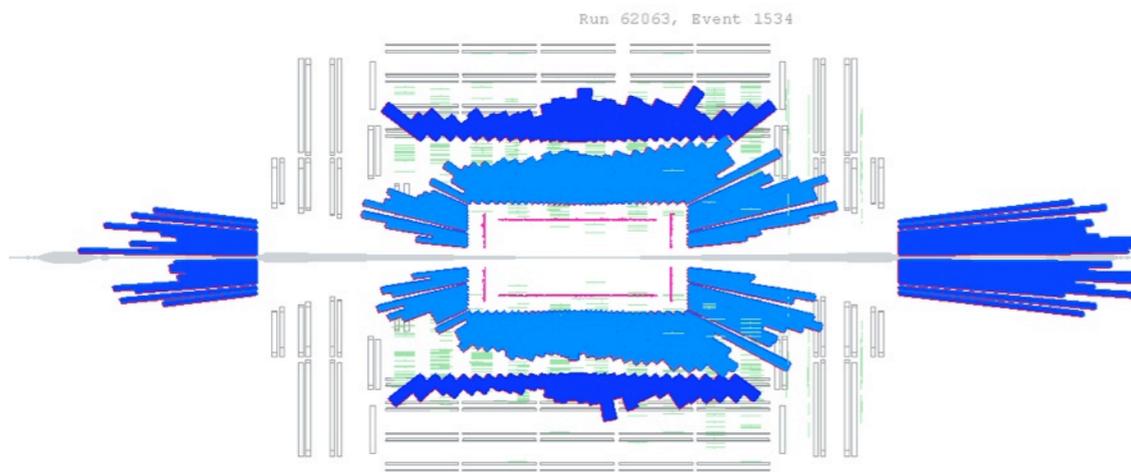
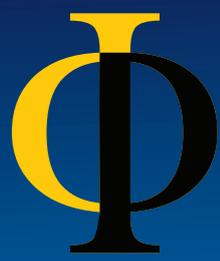


- **Hundreds of thousands** of muons pass through CMS per event from both sides
- Enormous amount of energy deposited in calorimeters
- Allowed **synchronization of triggers** (previously with cosmic muons)
 - Muon end caps, BPTX beam pick up, etc
- Internal synchronization of sub-detectors

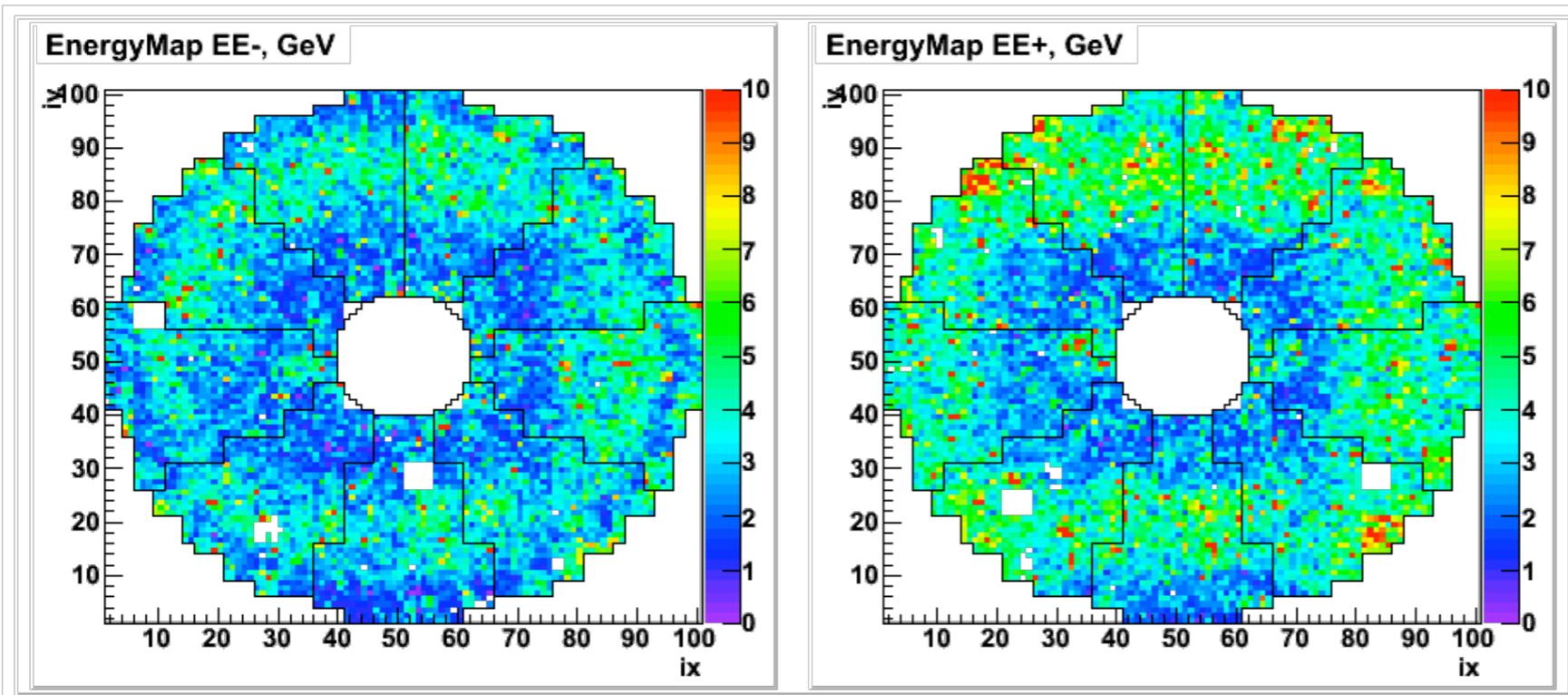




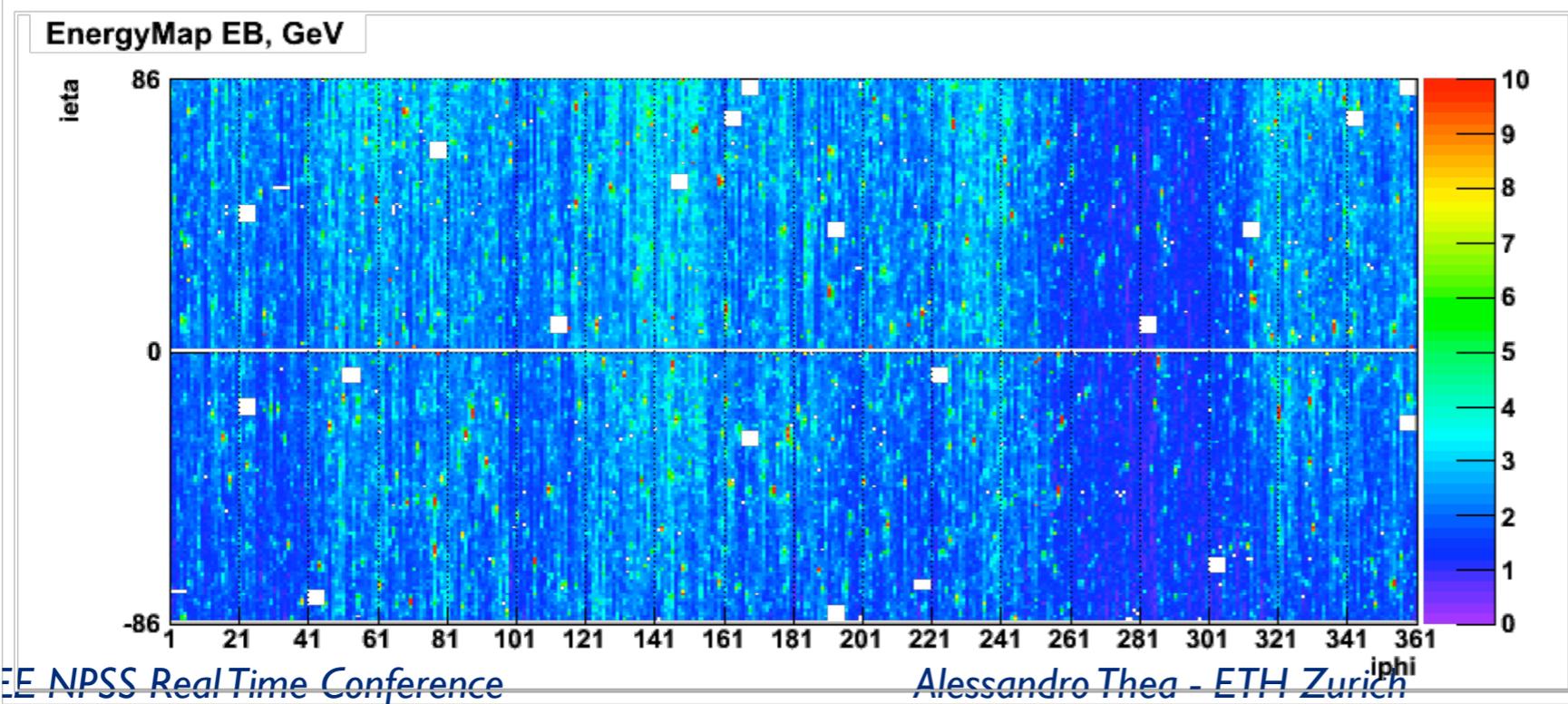
LHC Beam Splashes in CMS

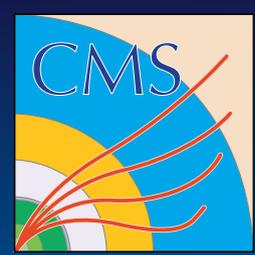


ECAL
HCAL
Drift Tubes
Inner Tracker OFF

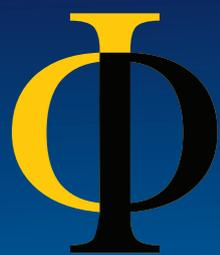


- More than 99% of ECAL channels fired
- Few $\times 10^5$ muons deposit ~ 200 TeV in ECAL
- White areas are channels masked from read-out
- Endcaps are not intercalibrated.
- Lowest LY channels near the beam pipe

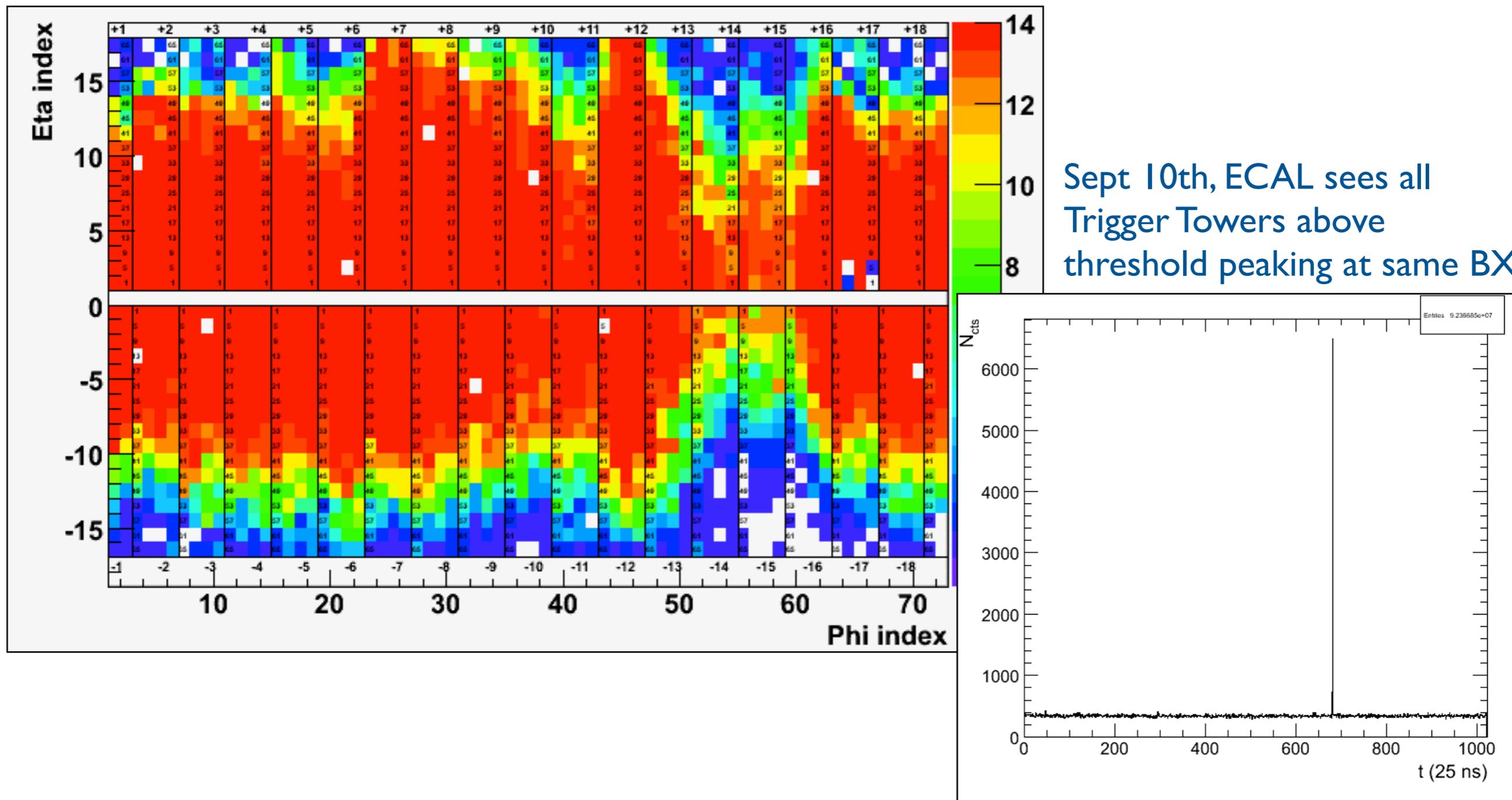


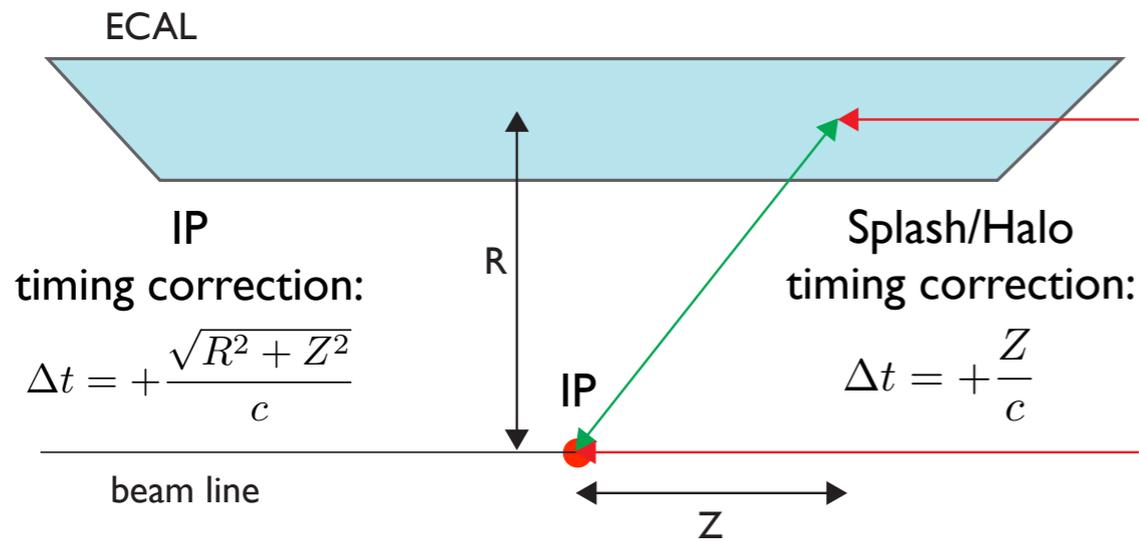


Beam Splash in the Monitoring

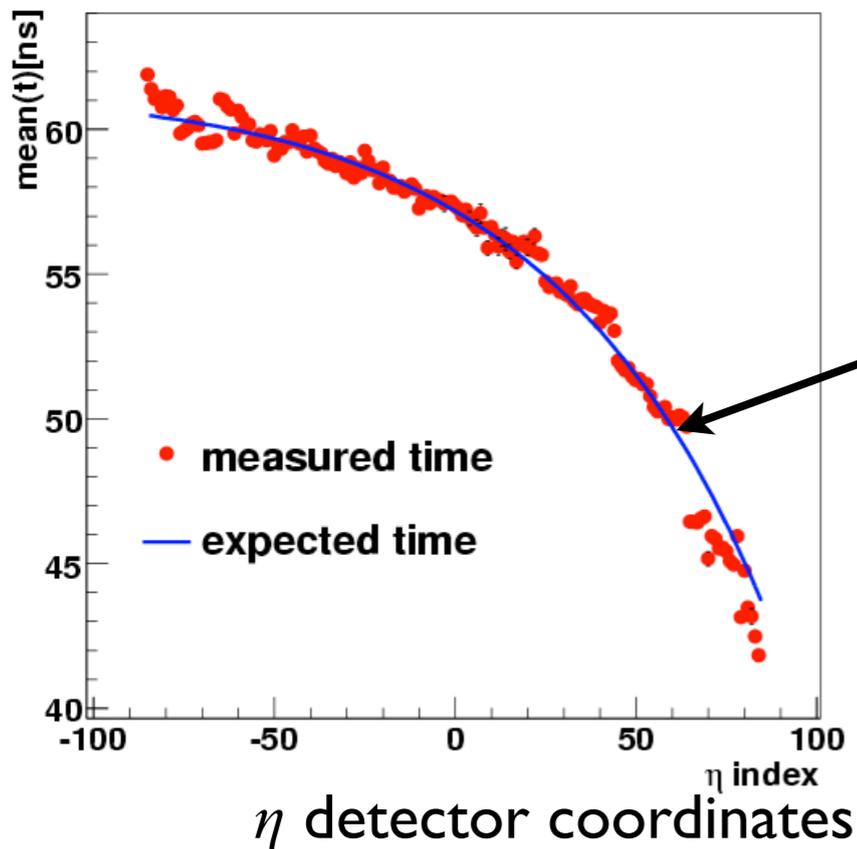


ECAL Trigger Primitives occupancy for $E_T > 25$ GeV



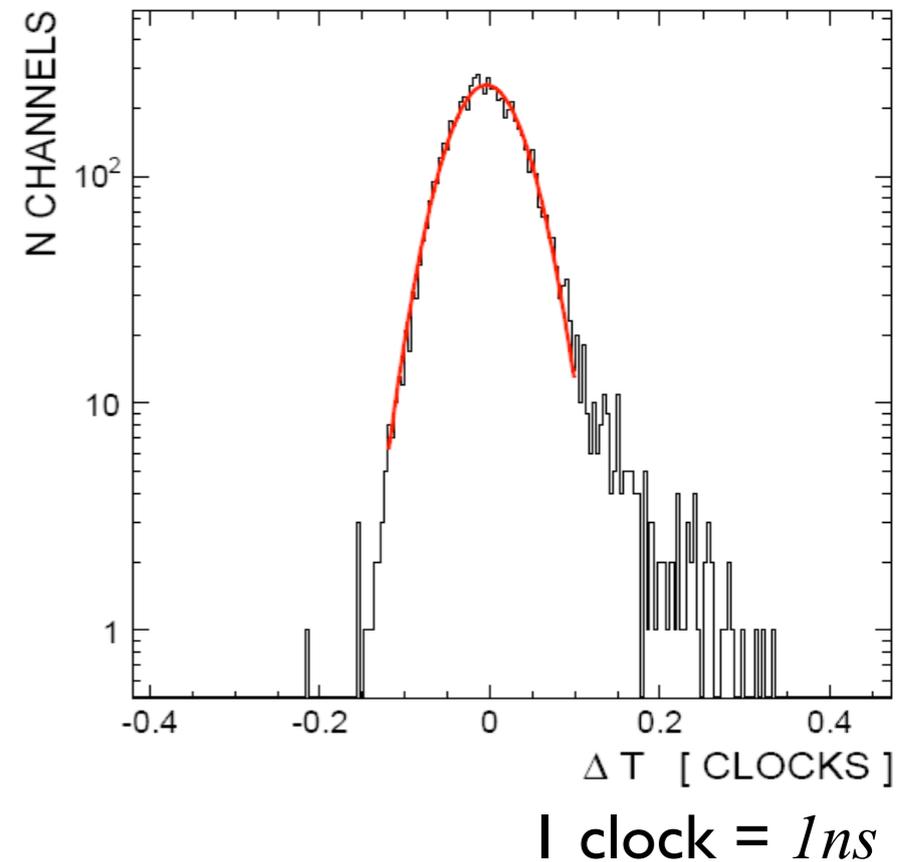


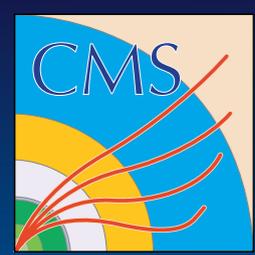
Splash events:
wonderful source of
synchronous hits over the
whole detector



Previous settings based on
synchronization with laser
events (fiber length to
reproduce collision timing)
**Splash events allowed
to time in the detector
at 1ns level**

Time resolution within
a tower $\sigma = 1 \text{ ns}$

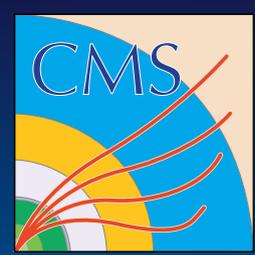




Summary



- **2008, a long year**
 - ▶ ECAL (Barrel + Endcap) is installed, signed off & taking data
 - ▶ More than 300M cosmics data acquired with $B=0$ T + almost 300M comics data @ $B = 3.8$ T
 - ▶ Spectacular splash events from LHC beam dump on collimators seen by ECAL: source for timing and signal studies
- **Physics results**
 - ▶ dE/pdx
- **Understanding ECAL**
 - ▶ Timing
 - ▶ Amplitude
 - ▶ Problematic Trigger Towers and Channels
 - ▶ Trigger and readout thresholds
- **Interplay with CMS**
 - ▶ Synchronization with the other subdetectors, calibration sequence, global trigger...



Spares



Commissioning of ECAL Trigger Primitives

- Based on the comparison with an ECAL-TP Emulator
- Hardware description at bit level (linearizer, filter, peak finder, compression etc)
- Used for LI studies (MC Production) and monitoring of hardware
- Initially checked with test beam data

