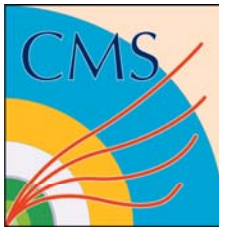


CMS Tracker Services: present status and potential for upgrade

Robert Stringer

University of California, Riverside

On behalf of the CMS Tracker Collaboration

CMS Silicon Strip Tracker

- Largest Silicon Detector ever built
  - 206 m^2 active area
  - 15232 Modules
  - Almost 10 Million readout channels!
- Immense size requires new procedures for installation.
  - Systematic testing

Service Electronics

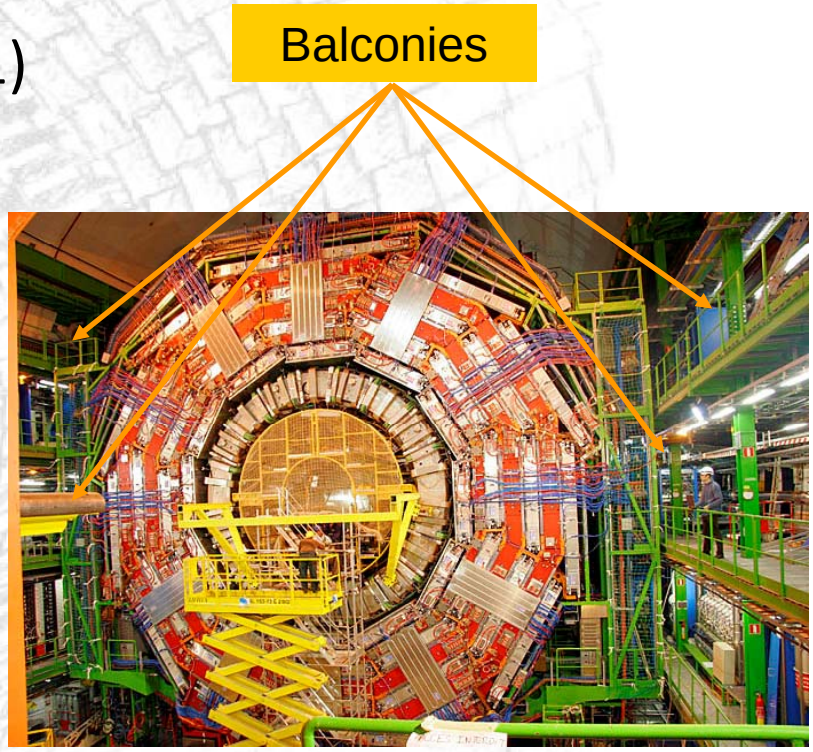
- 2000 CAEN LV/HV power supplies
- 4 CAEN Mainframes
- 7 PLC Systems
- 1000 Temperature and Humidity Probes
- 440 FEDs (80% of all FEDs in CMS)

Pre-Installation

- Services
  - Cooling
    - 980 Pipes
  - Power
    - 2300 Cables
  - DAQ
    - 3347 Fibers

PP1 Checkout

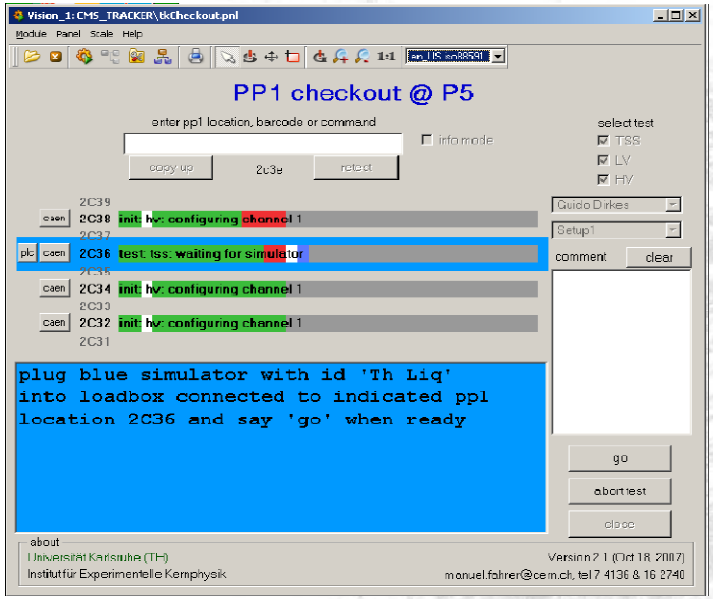
- 2300 power cables must be connected from 29 racks in 6 balconies to 28 Patch Panels (PP1) in YB0.
  - Each cable has unique id (barcode)
  - Online cable DB maintained.
  - Configuration DB contains all hardware and software maps.

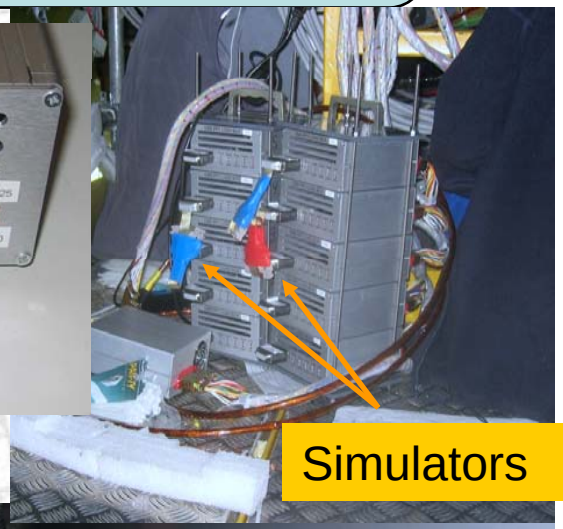


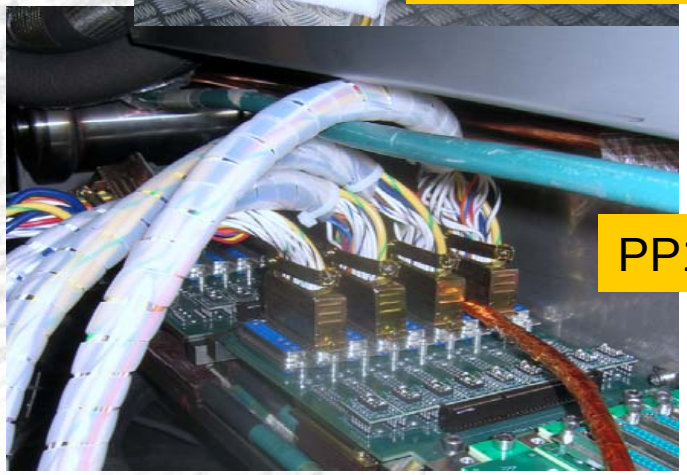
TCS & TSS

- The Control System and Safety System relies on the hardware and software maps
  - PP1 Checkout is the final test to assure that the map in the Configuration DB matches reality.
    - We check:
      - Physical cable map from PS racks to PP1
      - Physical cable map PLCs to sensors
      - Physical cable map of Interlock cables/relays
      - Logical map of PS and sensors in TCS
      - Logical map of Interlock relays

Loadbox Testing







- Loadboxes were connected up to 5 at a time
- Probe simulators were attached
- Software powered appropriate power supplies and verified values.

Progress Monitoring

PP1 Checkout Status Overview

Switch to Detail View Switch to Detail2 View

95.12 -11A	78.05 -12A	78.38 -13A	97.62 -14A	81.40 -16A	92.50 -17A	90.70 -18A	85.37 -2A	82.05 -3A	91.89 -4A	97.56 -5A	100.00 -7A	90.24 -8A	79.07 -9A
95.00 -11C	75.61 -12C	90.24 -13C	82.93 -15C	90.24 -16C	80.49 -17C	81.40 -18C	86.05 -2C	83.72 -3C	95.12 -4C	92.50 -6C	95.12 -7C	82.50 -8C	93.02 -9C
92.68 11A	92.50 12A	92.50 13A	70.00 14A	93.02 16A	95.45 17A	90.24 18A	100.00 2A	100.00 3A	97.14 4A	100.00 5A	95.24 7A	87.80 8A	92.86 9A
69.77 11C	83.33 12C	89.19 13C	72.09 15C	81.08 16C	95.24 17C	85.71 18C	95.56 2C	100.00 3C	100.00 4C	100.00 6C	91.89 7C	83.33 8C	88.10 9C

- Results stored in DB
  - Webpage showed status
  - Approx. 5% of cables had problems

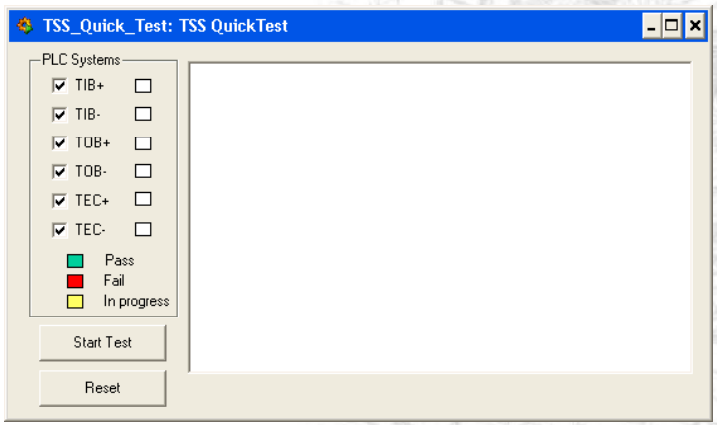
	3C1	3C2	3C3	3C4	3C5
1				Unused	
2	LV	LV			
3					
4					
5					
6					LV
7				LV	
8				LV	
9			LV		

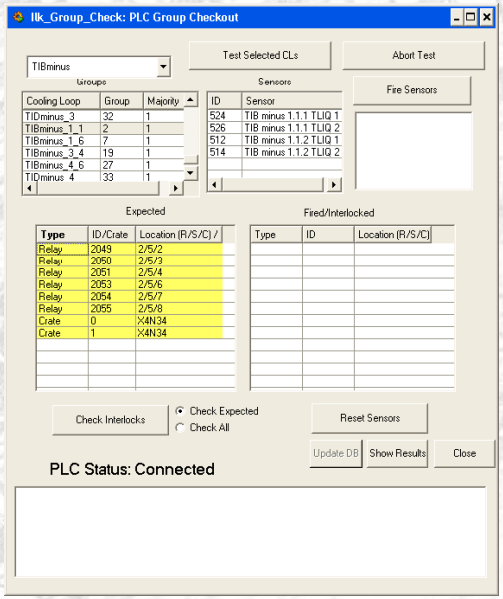
Tracker Safety

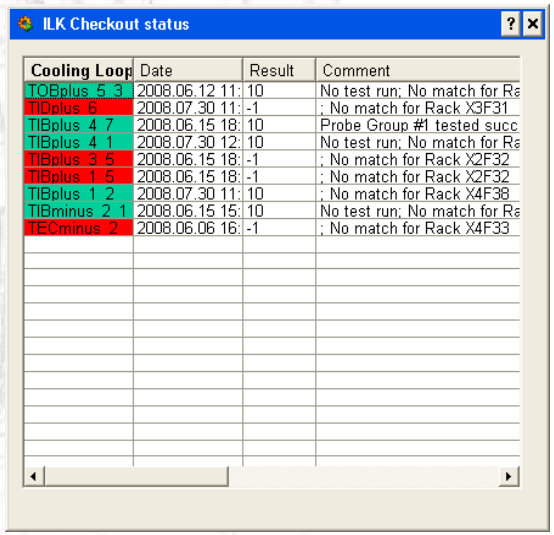
- Cable Map Accuracy
  - Need to power correct detector elements
  - Control hierarchy based around cooling geometry
    - Errors in cable map could result in powering elements without cooling, endangering the tracker.
    - Errors in software map could cause wrong elements to be shutdown in a dangerous situation.

Interlock Tests

- Interlock Cables run from relays to racks.
  - Each rack has a distribution box to separate to each crate.
- Software tools verify physical cable map and software logic





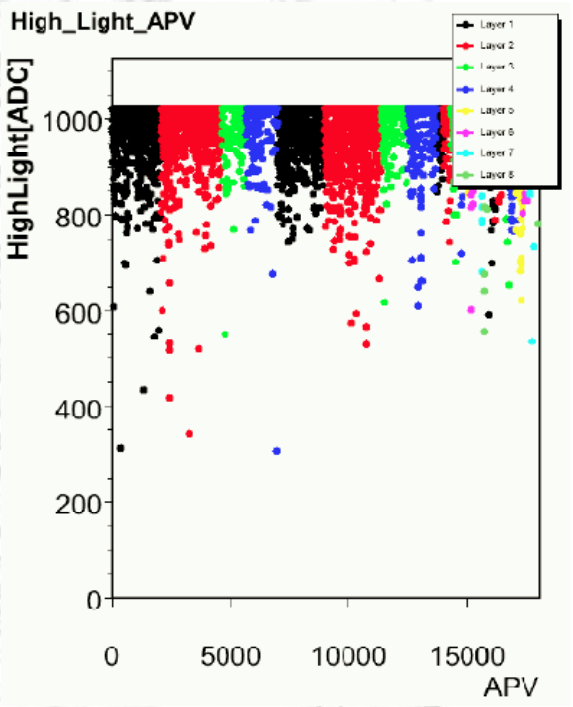


TKCC

- Tracker Connection and Checkout (TKCC)
  - DCU/CCU Scan
    - Tracker elements are powered and readout one at a time to detect swapped power cables.
  - Connection Run
    - DAQ is read out to verify fiber connections.
  - Timing Run
    - Synchronize all channels, latency due to different cable lengths
  - Gain Scan
    - Determine optimum bias and gain settings
  - Pedestal Run
    - Store pedestals to DB & noise studies

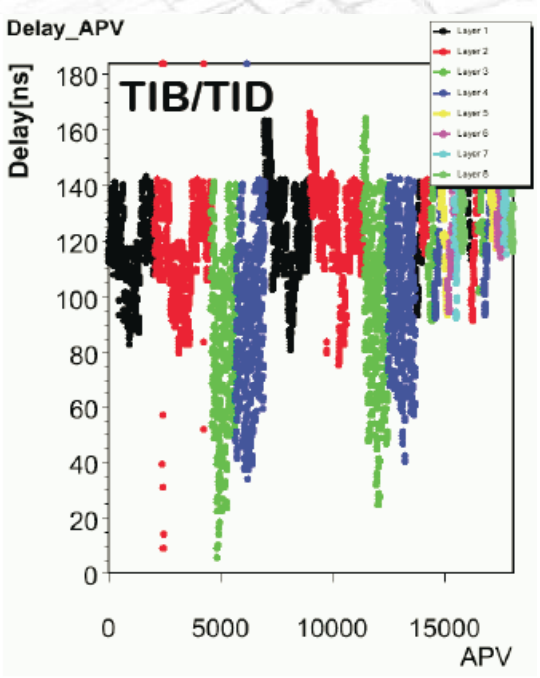
TKCC

- Connection Run
  - Light levels for each fiber are measured
  - Low saturation light levels identify bad connections or dirty fibers

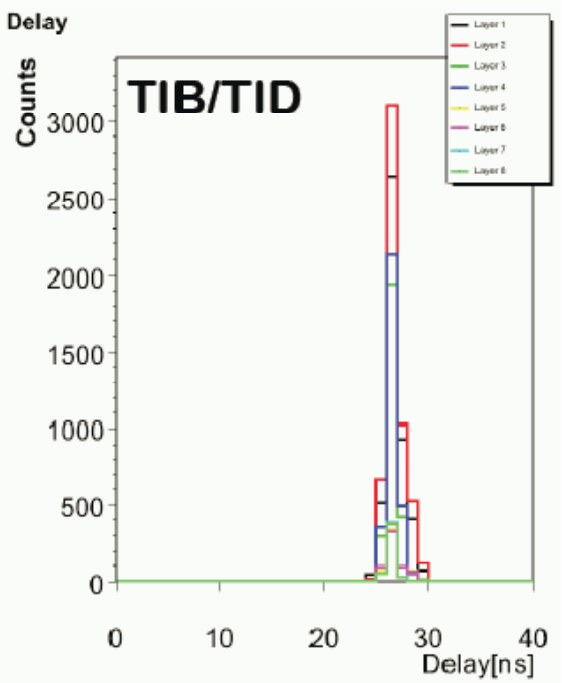


Synchronization/Latency

- Timing run
  - Send simultaneous trigger
  - Response measured
  - Adjust latency



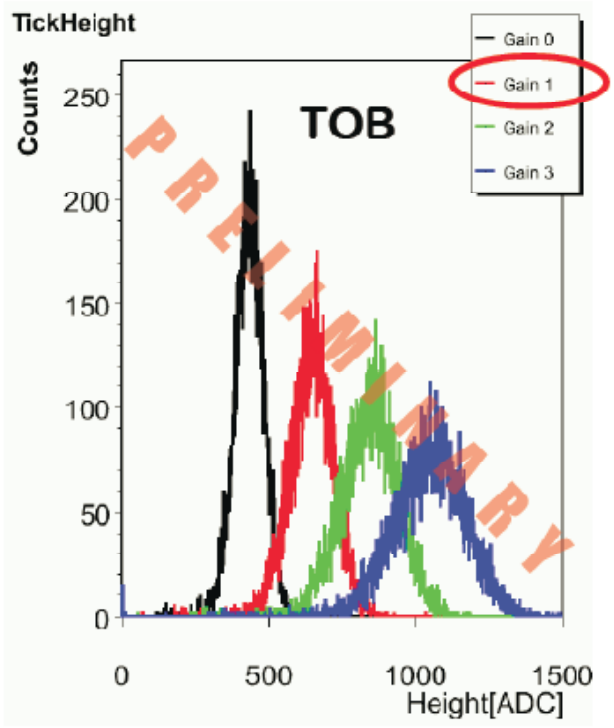
Before



After

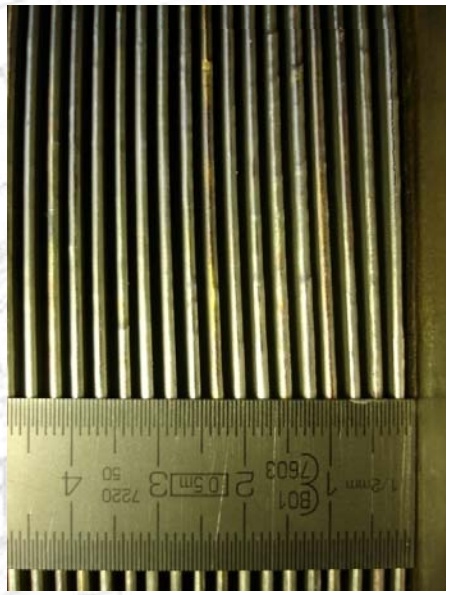
Gain Scan

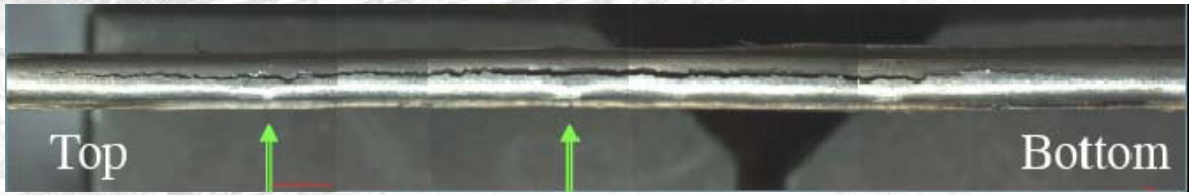
- Laser provides signal
  - Optimal gain chosen



Cooling

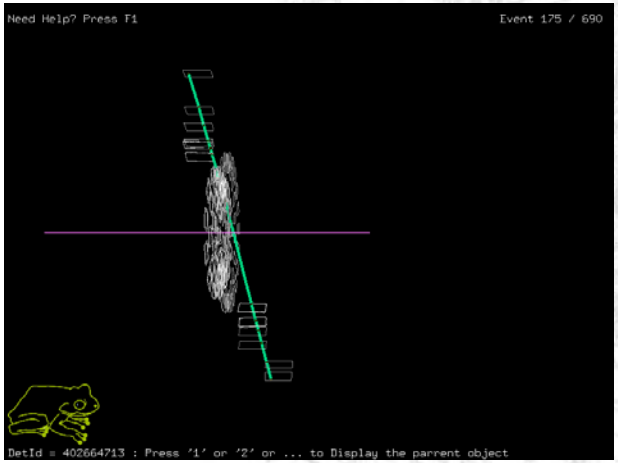
- Heat Exchanger Failure
  - Brine contaminated C_6F_{14}
  - This would have been a disaster if tracker was connected (it wasn't!).
- Brine was replaced by C_6F_{14}
  - A similar failure will not endanger tracker.

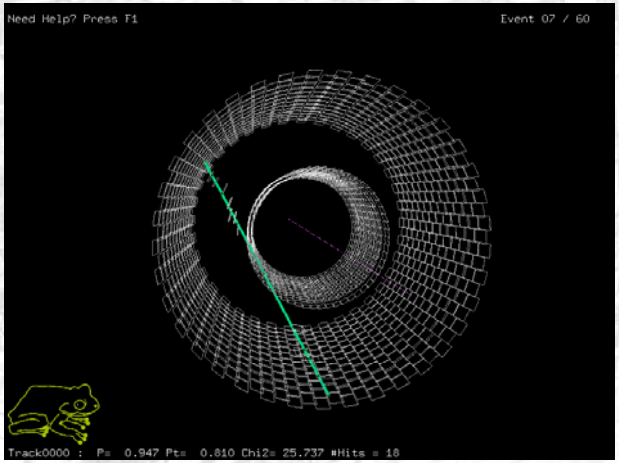


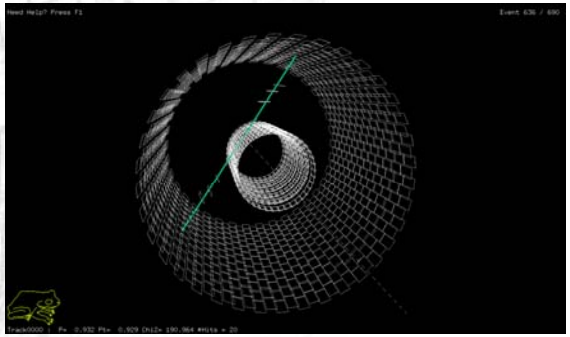


First Cosmics

- The Tracker participated in CRUZET3
  - Cosmic Run Under ZEro Tesla
  - Over 12 Million Cosmic events were taken.







First Beams

- Tracker was OFF during First Beam event on Sept. 10
  - Once it is determined that it is safe for the Tracker it will be turned ON.
  - Using BLM & BCM data we saw nothing that would endanger the Tracker.

SLHC Upgrade

- Effect on Tracker
  - 20x more particles in the Tracker

	LHC	SLHC (Phase 2)
peak luminosity	10^{34} cm^{-2} s^{-1}	10^{35} cm^{-2} s^{-1}
integrated luminosity	100 fb^{-1}/year	1000 fb^{-1}/year
c.m. energy	14 TeV	14 TeV
bunch crossing interval	25 ns	50 ns (?)
# pp events / crossing	~20	~400
# particles in tracker	~1 000	~20 000

SLHC Upgrade Potential

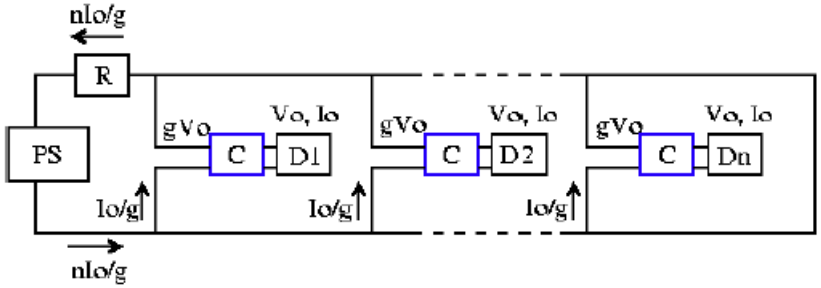
- Requirements for the SLHC environment
  - Higher Luminosity implies:
    - Trigger (for other subdetectors)
      - High Pt
    - Higher Radiation
    - Shorter strips -> More channels
      - Lower power consumption
  - Material budget
  - Power cables and cooling pipes can be reused!

SLHC Tracker Power

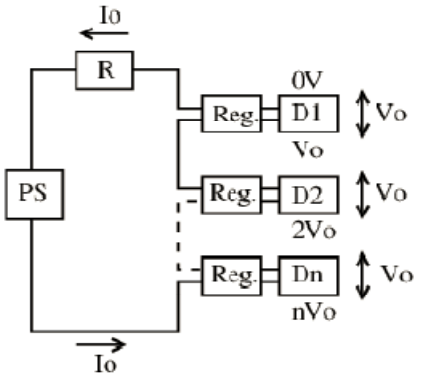
- To handle increased radiation readout chips will be made with smaller feature size
  - At most 0.13µm
  - Smaller features result in lower voltage (~1.2V)
  - More channels make total power consumption comparable with current Tracker (~30kW)
  - Higher currents exceed the limits of the existing cables
    - A new powering scheme must be devised.

Power Schemes

- Studies have begun
  - DC-DC converters
    - Requires
      - Low-noise
      - Radiation hard
      - 4T tolerant
  - Serial Powering
    - Different grounds
    - Loss of chain



$g = V_{in} / V_{out} >> 1$ $P_{drop} = R \cdot I_0^2 \cdot n^2/g^2$



$V_{drop} = R \cdot I_0$
$P_{drop} = R \cdot I_0^2$

SLHC Tracker Cooling

- Lower operation temperature (-50°C)
  - Better for high radiation environment
  - Lower leakage current
- Considering CO_2 Cooling
  - Could use smaller pipes, lower material budget
  - R & D has started.

Conclusion

- Size of the CMS Tracker required systematic checkout.
  - Software and Hardware tools were developed
  - All aspects were tested (Power, Control, DAQ)
  - Checkout went smoothly and was only slightly delayed by cooling problems.
- The CMS Tracker is commissioned and is ready for physics with 99.7% of channels operating!

Conclusion

- SLHC Tracker R&D is underway.
  - Power Cables and Cooling pipes will be reused.
  - Modified powering schemes are being tested to handle higher currents.
  - CO_2 cooling is favored.
- There is a good potential for reuse of materials for the SLHC Tracker!