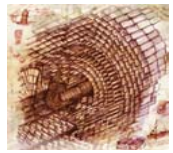


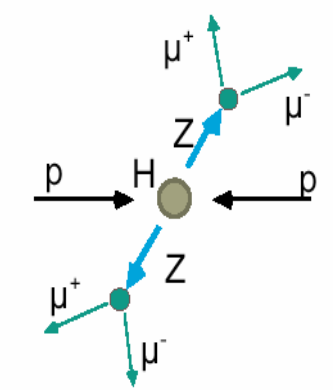
The CMS Tracker

James Lamb

University of California, Santa Barbara

On behalf of CMS Tracker group

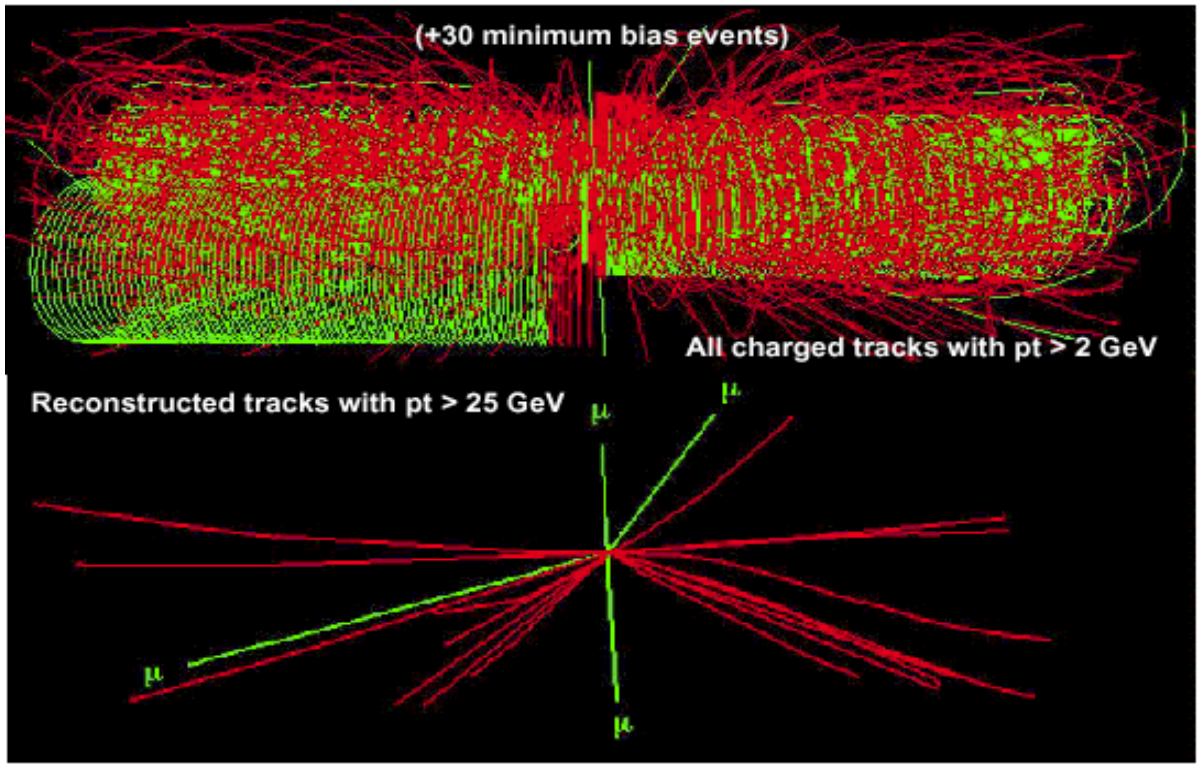
Tracking Objectives



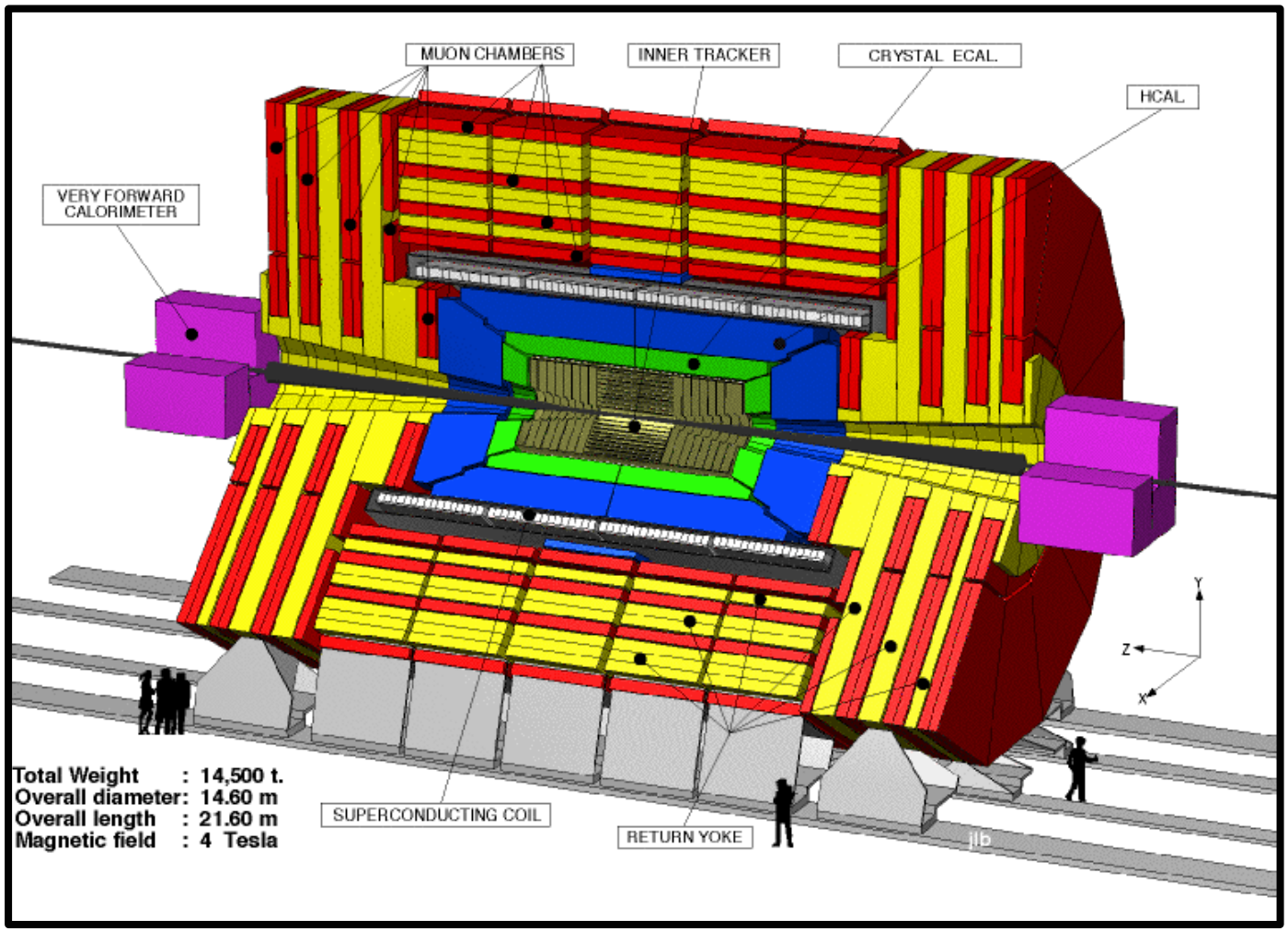
- Efficiency and p_T resolution of isolated leptons
  - Leptons: a clean way to characterize events involving gauge bosons.
  - Requires several high precision position measurements, and a minimization of material.
  - Planned resolution $\Delta p_T / p_T \sim 15 * p_T$ (TeV) % in central $\eta<1.6$ region, degrading to $\sim 60 * p_T$ (TeV) % at $\eta=2.5$.
- Tagging and reconstruction of b-jets
  - Useful signature of new physics.
  - Also useful for B physics.
  - For mistag rate of 1-2%, anticipate ~50% (central) to ~40% (forward) tagging efficiency.

Tracking Objectives

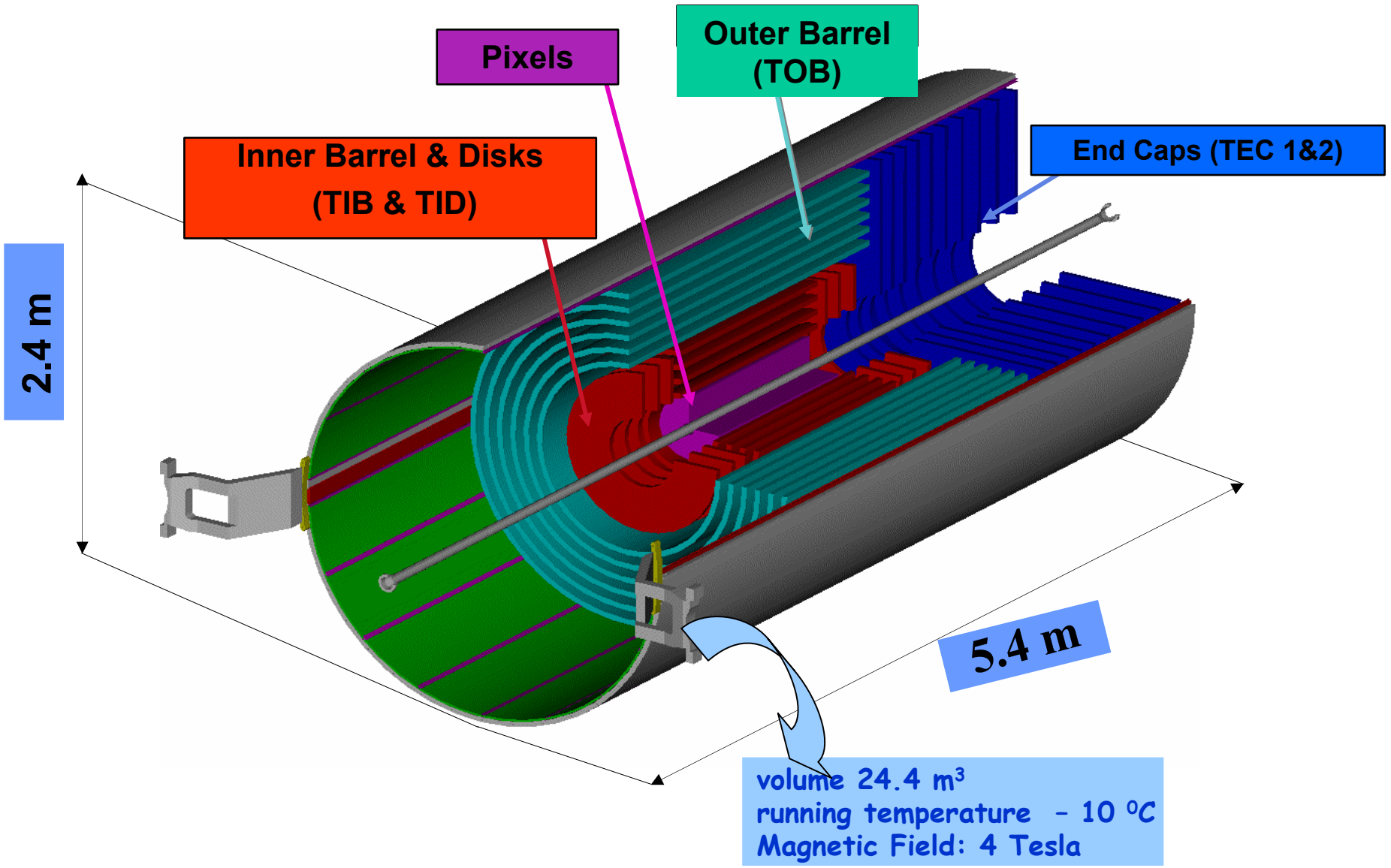
- High-luminosity environment
  - 20-30 min-bias events background per bunch-crossing.
  - High-radiation environment



The CMS Detector

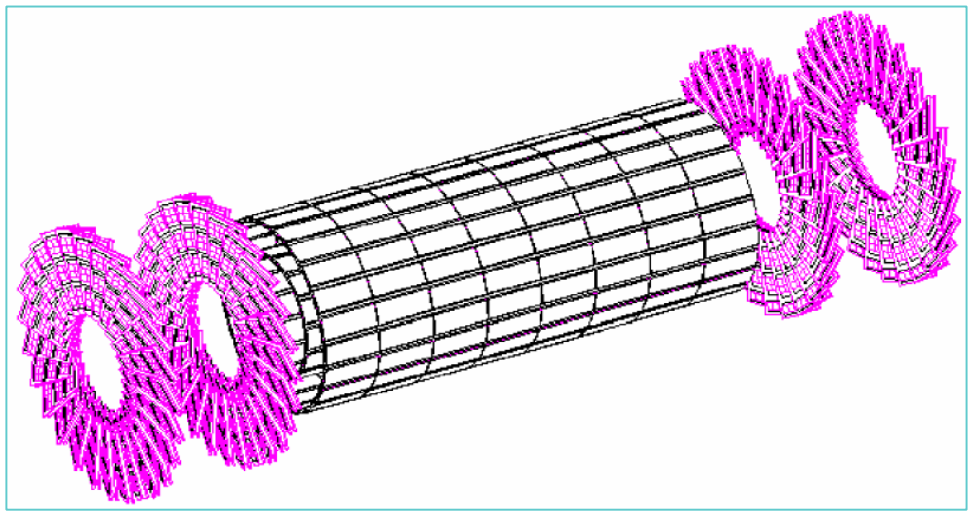


The Tracker


Pixels
Outer Barrel (TOB)
Inner Barrel & Disks (TIB & TID)
End Caps (TEC 1&2)
2.4 m
5.4 m
volume 24.4 m³
running temperature – 10 °C
Magnetic Field: 4 Tesla

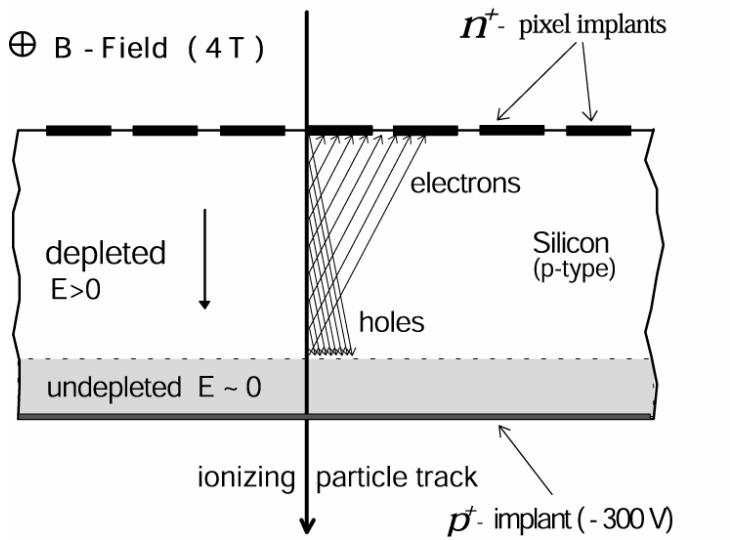
Pixels

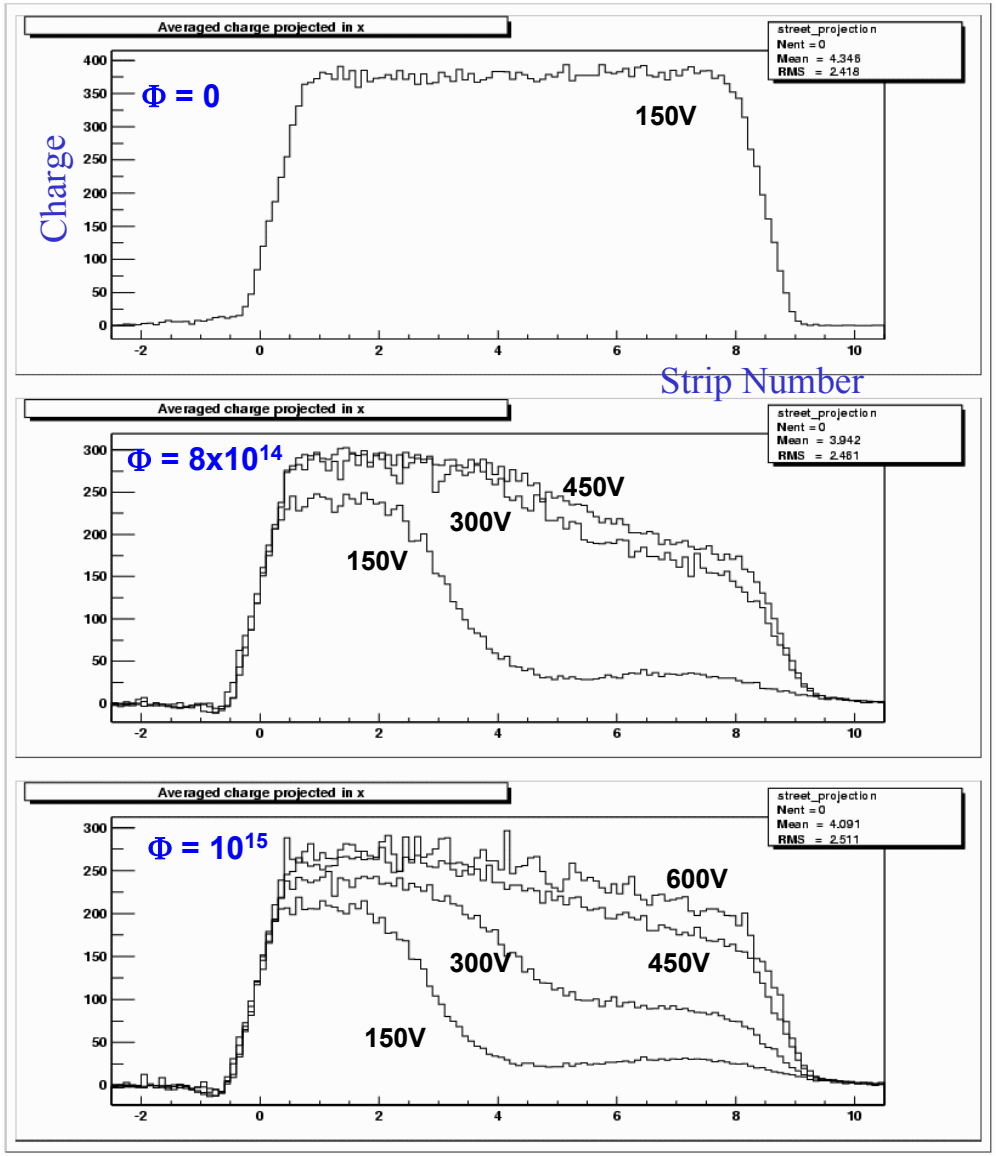
- Good resolution and low occupancy are a good start for tracking
  - Hit Resolutions: 10μm rϕ, 17μm z
- Vertexing
  - 20-70 μm primary-vertex resolution with pixels alone
    - Good enough and fast enough for high-level trigger
  - 15μm using full tracker
  - Secondary vertexing



Pixels: Radiation Resistance

- Low pixel capacitance
- Depletion starts at pixel electronics





Pixels

- Staged deployment of three layers
  - Initial layers at 4cm and 7cm
  - After 4 years, 4cm layer removed (TDR)
    - May last longer
  - By then the 11cm layer will be ready
    - Requires as many modules as both 4cm and 7cm layers together.
  - After 6 years, 7cm layer removed (TDR)
    - May last longer.

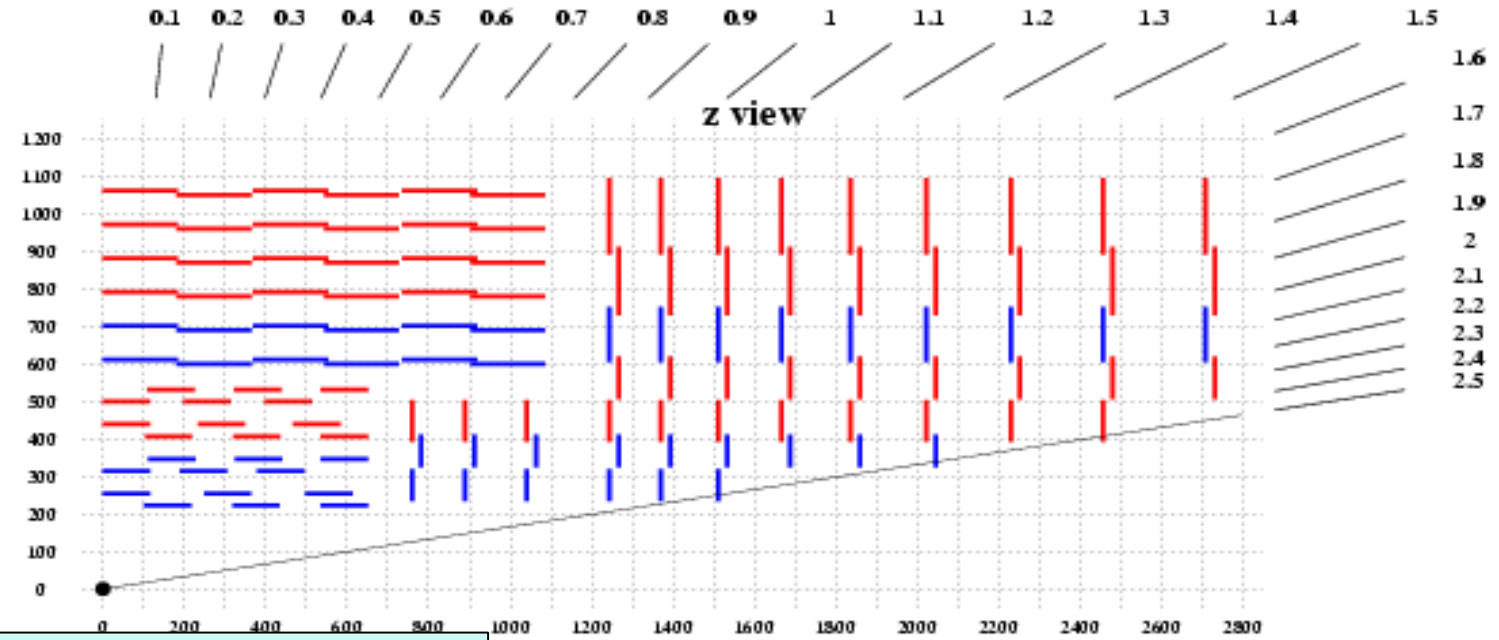
Pixels Status

- Mechanics in good shape
  - Tested pixel insertion in mechanic mock-up
- Sensors in good shape
  - Settling on final design. Should be available Dec. 2004.
  - Radiation resistant: S/N high. Can likely operate beyond timescales assumed in TDR.
- Readout chip (ROC) in good shape
  - Successfully translated to 0.25um CMOS technology
  - Radiation and SEU tolerant.
- Module production starts in Spring 2005.

Silicon Strip Tracker

6 layers of 500 μm sensors high resistivity, p-on-n

9+3 disks per end

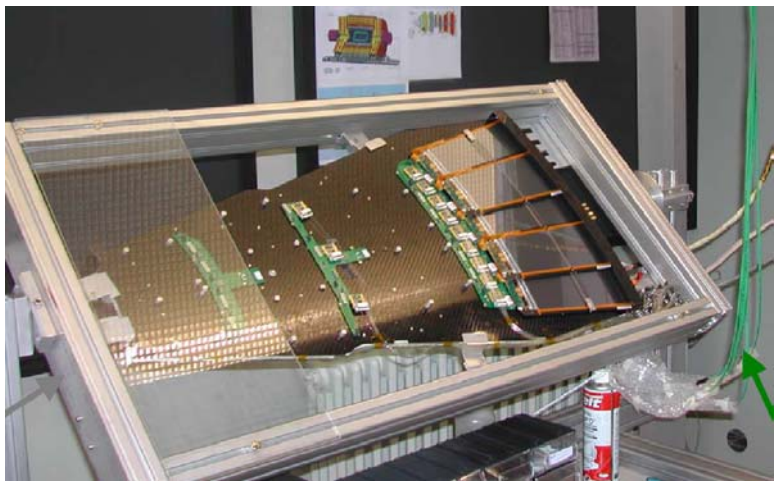


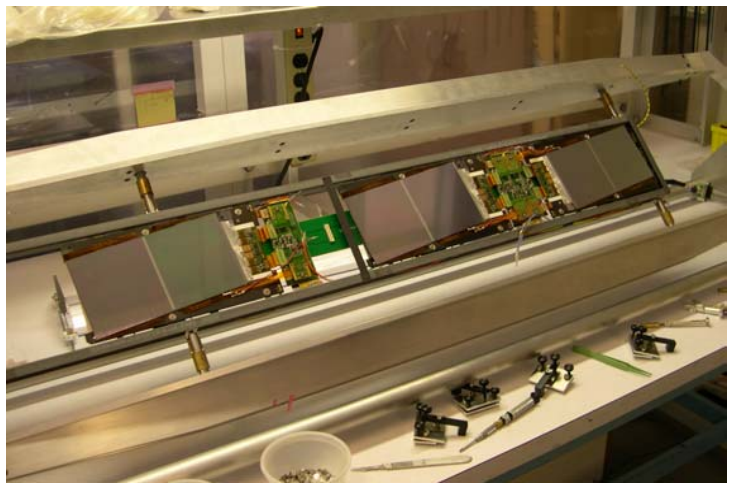
4 layers of 320 μm sensors low resistivity, p-on-n

Strip lengths range from 10 cm in the inner layers to 20 cm in the outer layers.
Strip pitches range from 80μm in the inner layers to near 200μm in the outer layers

Silicon Strip Tracker

- All-silicon tracker chosen for
  - High granularity
  - Speed
  - Radiation tolerance
- Novel features of this tracker
  - Small number of layers, but all of them good
  - Huge amount of silicon
  - Modular: ease of construction important

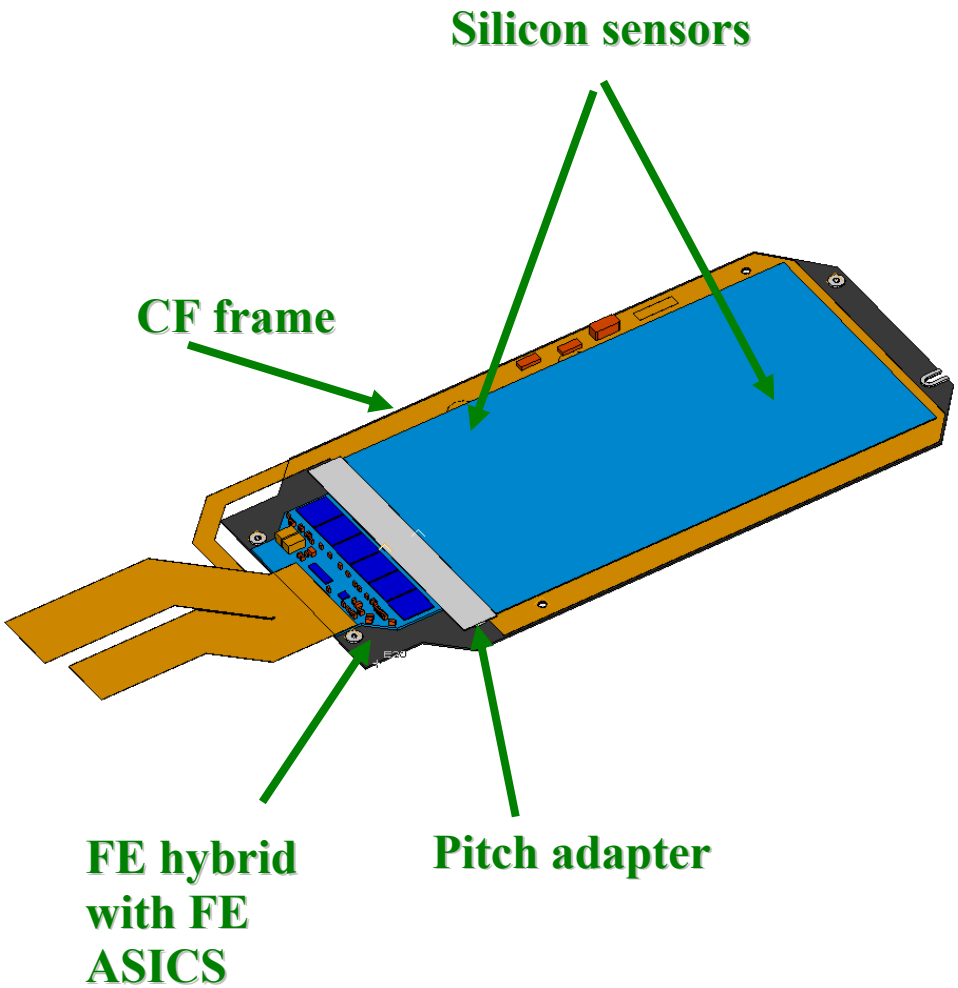




Silicon Strip Tracker

- All-silicon tracker enabled by
  - Industry-standard technology
    - Single-sided p-on-n
    - 0.25 um CMOS readout chip
  - Automation of Module Assembly

Some Tracker Numbers



- 6,136 Thin wafers 300 μm
- 19,632 Thick wafers 500 μm
- 6,136 Thin detectors (1 sensor)
- 9,816 Thick detectors (2 sensors)

- 3112 + 1512 Thin modules (ss +ds)
- 4776 + 2520 Thick modules (ss +ds)

- 10,016,768 individual strips and readout electronics channels

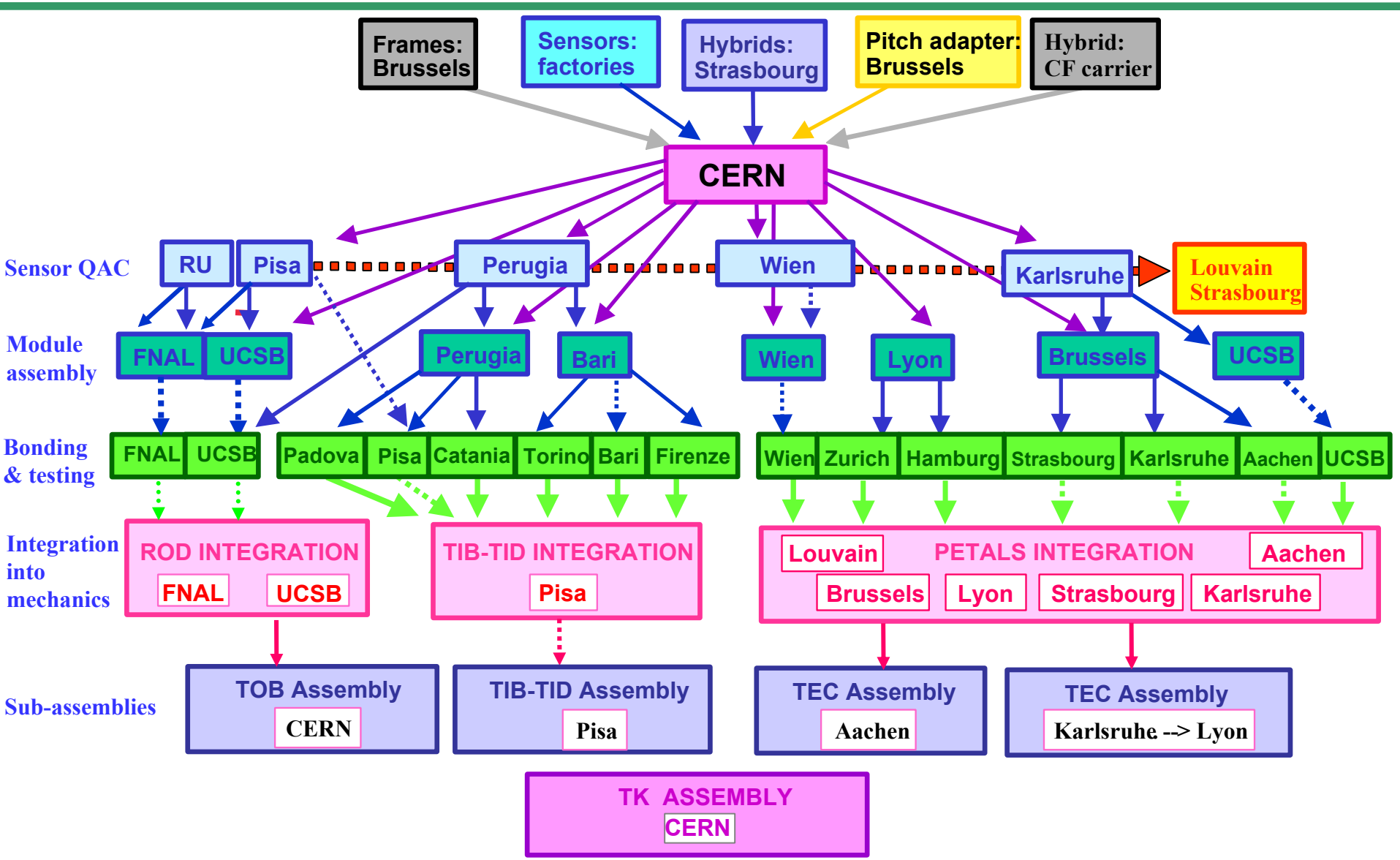
- 78,256 APV chips
- ~26,000,000 Bonds

- 470 m^2 of silicon wafers
- 223 m^2 of silicon sensors (175 m^2 + 48 m^2)

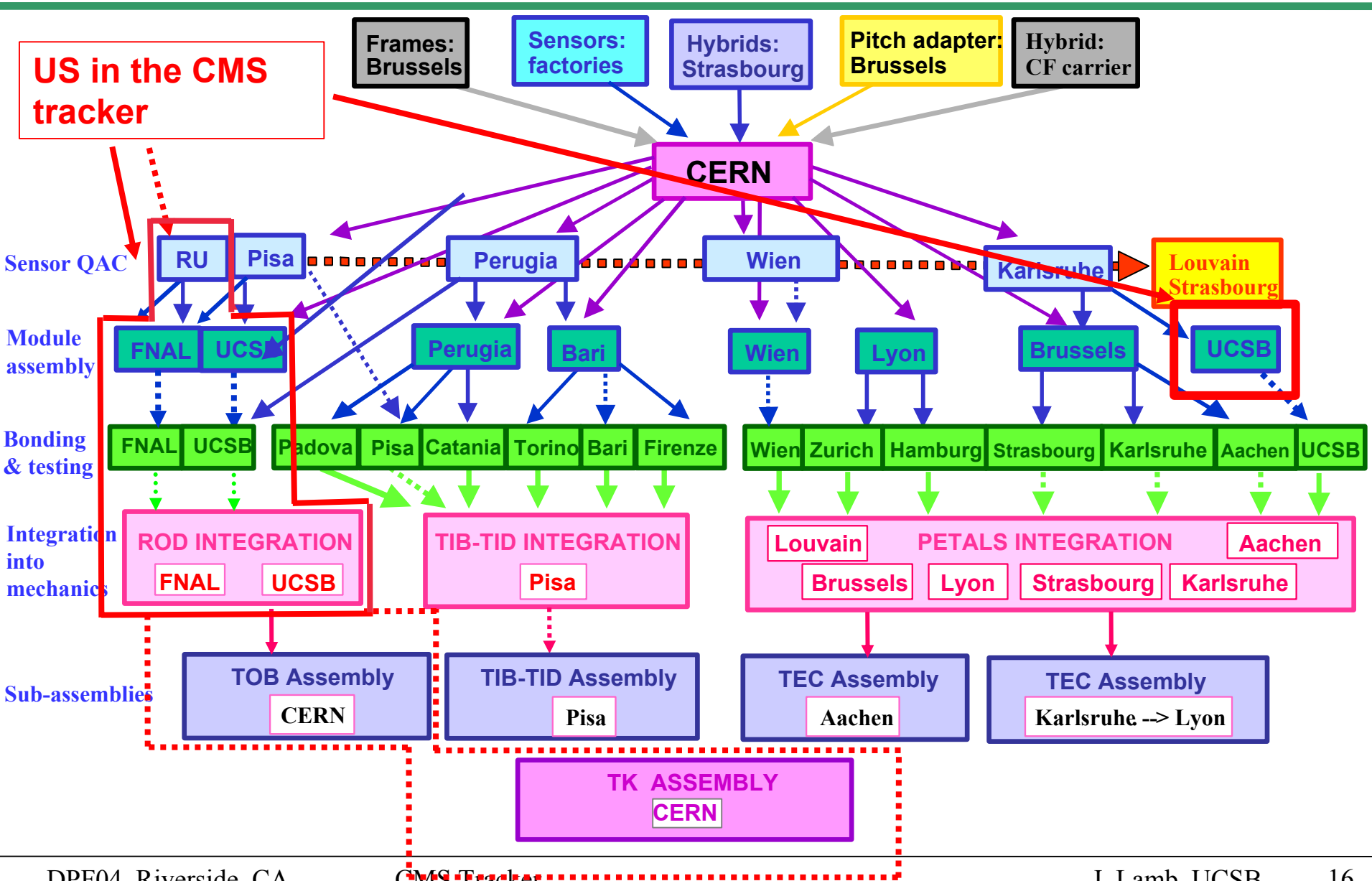
Silicon Strip Tracker

- Automated and distributed production
  - GANTRY computer-controlled assembly of sensors and hybrids onto frames
    - 15 minutes assembly time per module
  - Fast wirebonding times
    - 25 min total time to bond module and hybrid, including prep and database time
  - Production so fast, we are developing a “fast track” testing system to avoid wasting components in case of a production problem.
  - 7 module assembly centers, 17 module bonding and testing centers, 9 sub-detector assembly/testing centers.
  - US Responsibilities:
    - 2 Production lines (FNAL, UCSB)
    - ½ of all SST modules

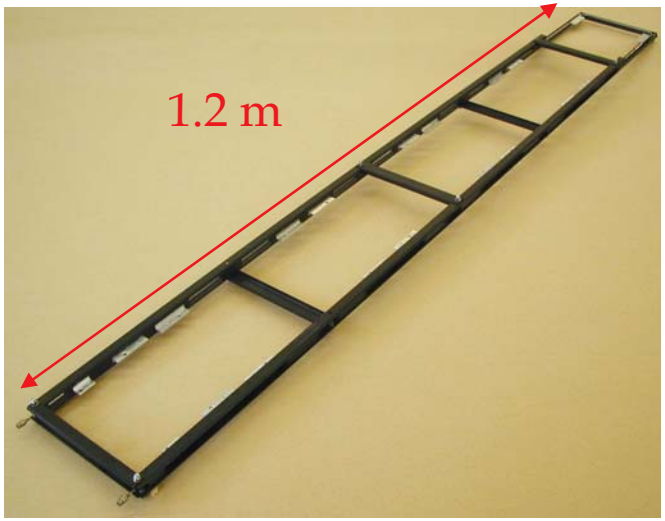
CMS SST Organization

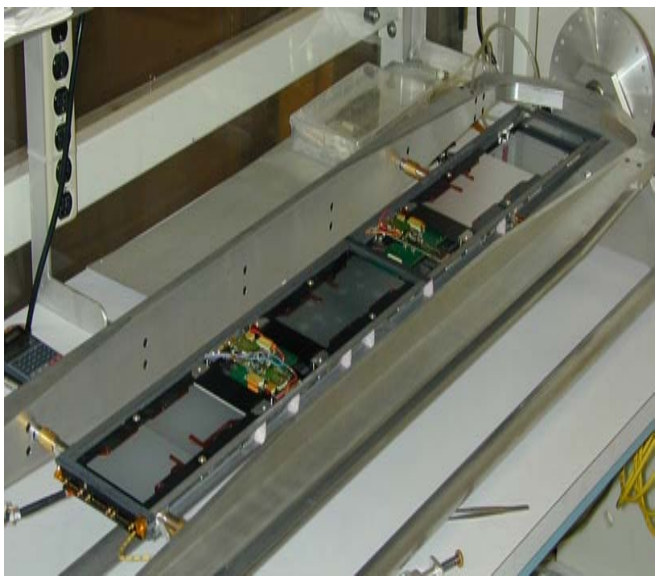


CMS SST Organization



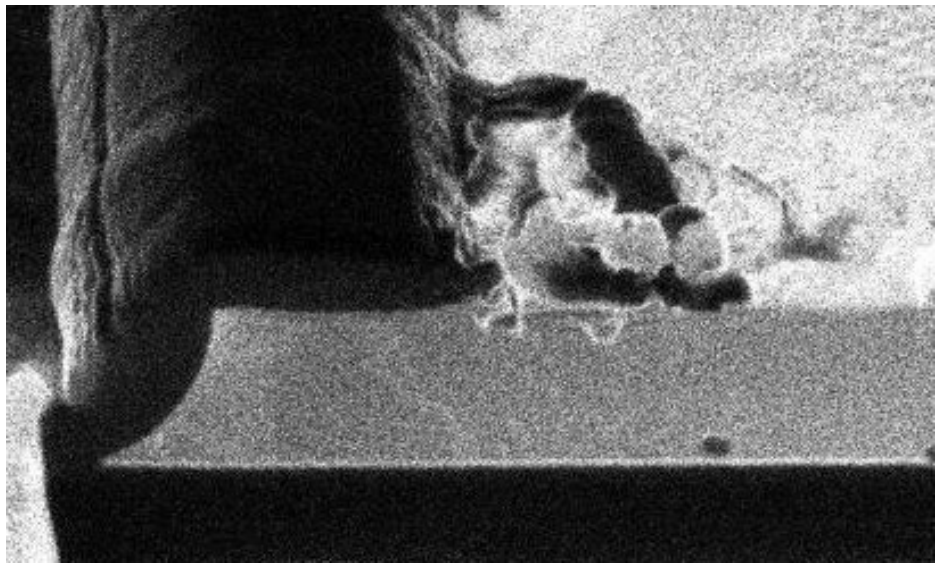
Tracker Mechanics

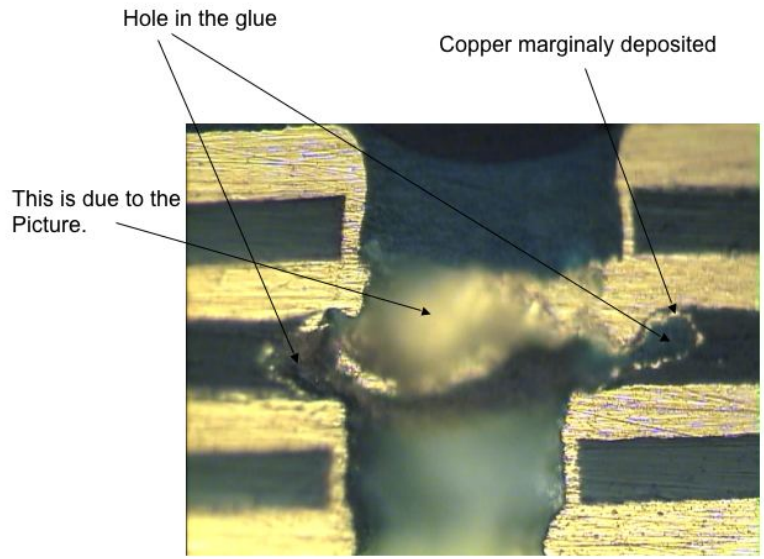




Problems

- Sensor problems
  - Instabilities found in original sensors
    - Working to correct problems
  - Meanwhile transferred most of the load to another vendor
- Hybrid problems
  - A couple of serious problems identified in the hybrids
    - Identified and solved through good relationship between US, CERN, vendor
- Transport Problems
  - Never before has a project required such large-scale distributed production
    - Some problems bound to happen
  - Problems identified, and solved using "packaging science"
    - Vibration table
    - Precision "drop test"





SST Module Prod. Status

- Inner Tracker (barrel/disks)
  - Production well under way
    - 30 % of 3830 modules produced
- Endcaps:
  - Production under way
    - Demonstrated capacity of 30 mods/day
- Outer Tracker:
  - Production under way
    - Demonstrated capacity of 30 mods/day

      US Built 300 modules in a 2 week period.
    - US expects it can reach 50 mods/day with modest increase in manpower, no new equipment

SST Mechanical Status

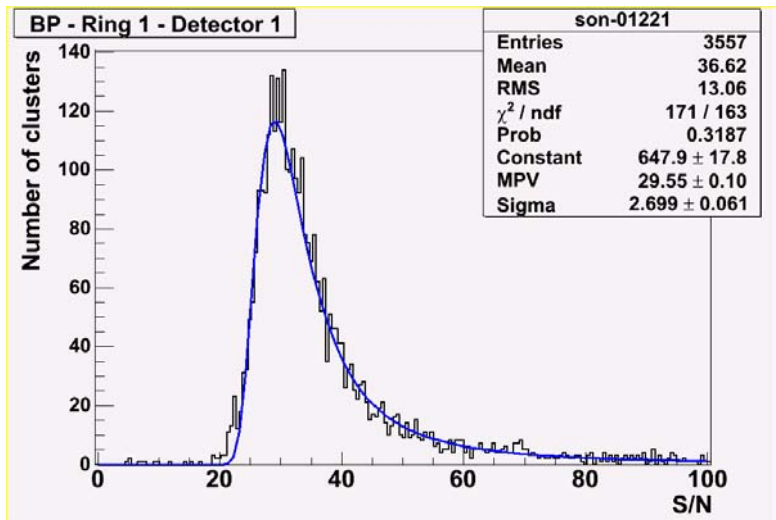
- Inner Tracker:
  - Practice integration done on partial mock-up. Final tooling in preparation.
- Endcaps:
  - Production of sub-detectors ("petals") underway.
- Outer Tracker:
  - Barrel completed and delivered to CERN

SST Mechanical Status

- Tracker support "Tube" on its way to CERN

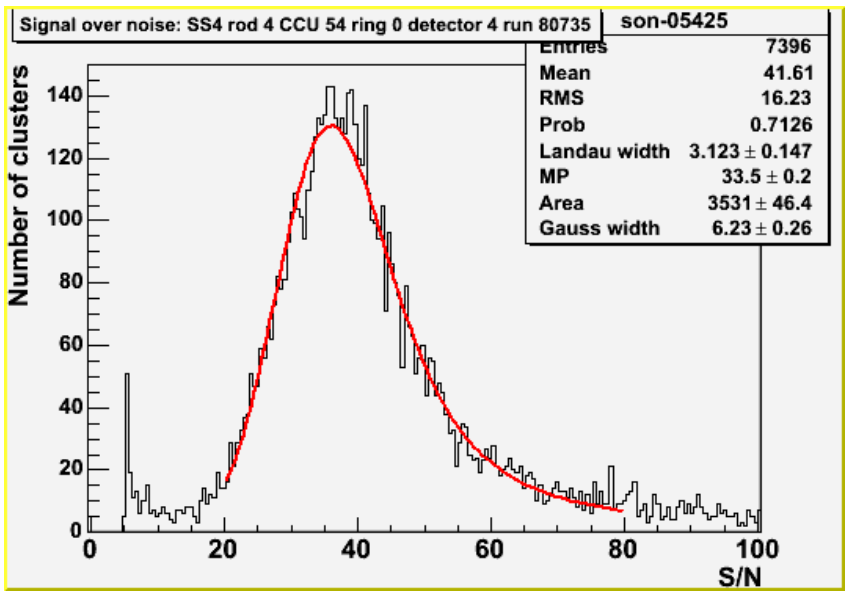
SST Test Beam Status

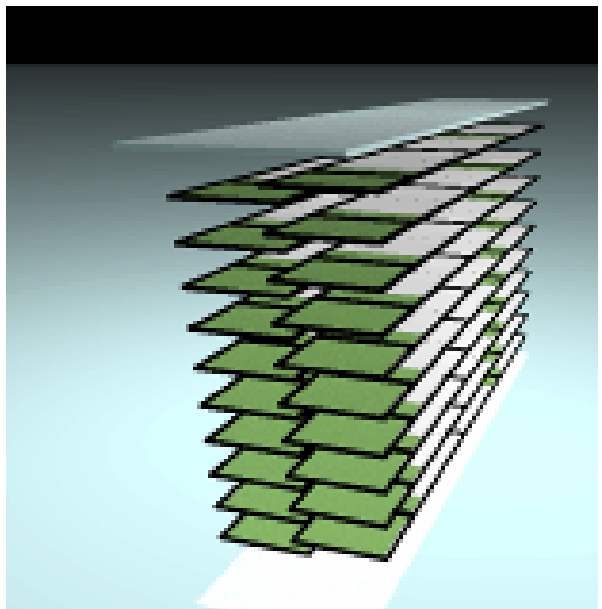
- Inner Tracker:
  - Modules performed as expected in test beam.
- Endcaps:
  - Full control ring (2 petals, 51 modules) put in May 2004 test beam.
    - Operated as expected.
    - Detector S/N ~ 30



SST Test Beam Status

- Outer Tracker:
  - Barrel-similar structure ("CRack") in May 2004 test beam.
    - Operated as expected.
    - S/N > 30
    - Reconstruction and analysis done with prototype version of final software ("ORCA")





Installation

- Installation of Tracker starts August 2006.
- “Pilot Run” without completed Pixels starts May 2007
- Pixels installed Nov/Dec 2007.
- Ready for physics: April 2008

Conclusion

- Pixel detector on track, but still a lot of work to be done.
- Much of the Inner Tracker done. The rest on track.
  - Majority of modules produced.
  - Integration of sub-detector later this year.
- Outer Tracker has faced and overcome "teething" problems. Now ready for production.
  - Validated our QA
  - Demonstrated planned production rate, and can increase if necessary.