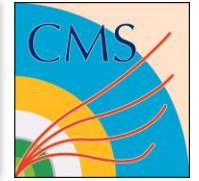




# The CMS All Silicon Tracker: Lessons Learned and Future Prospects



June 2009

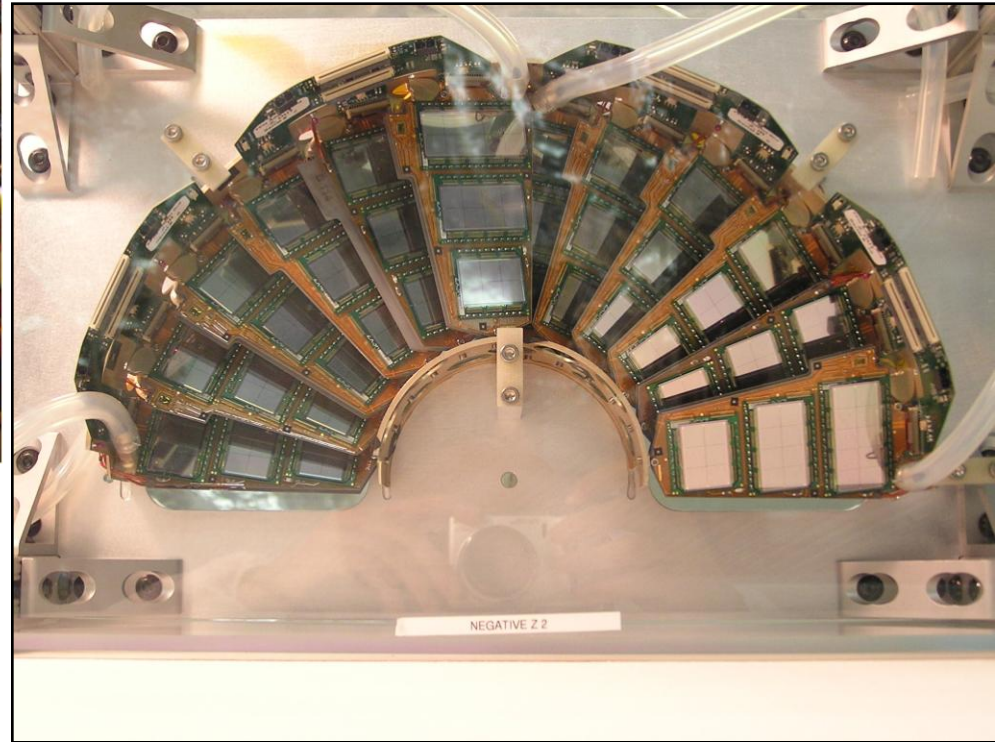
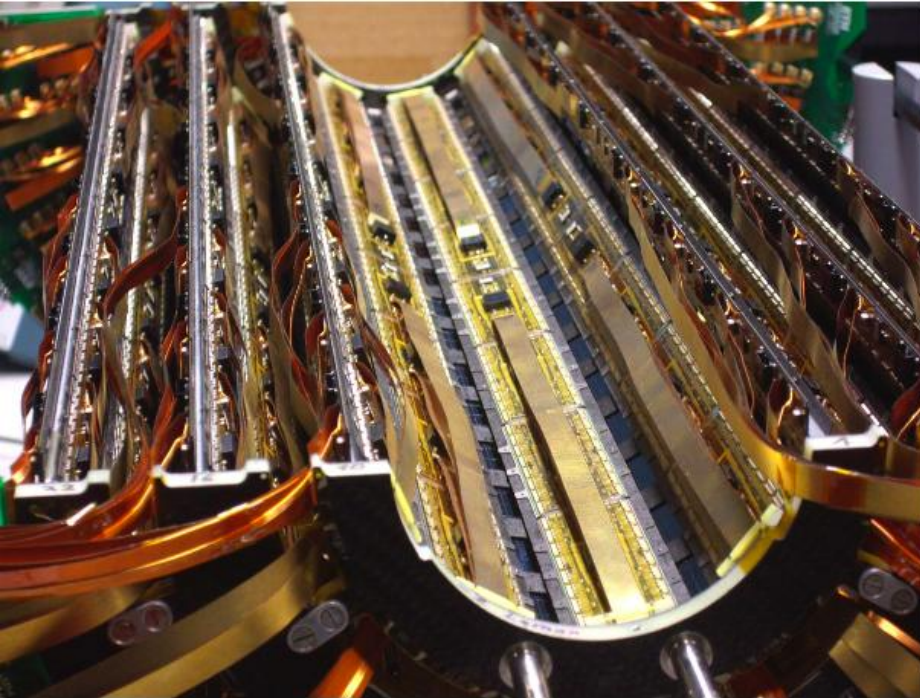
The CMS All Silicon Tracker, Lessons Learned and  
Future Prospects

Marcello Mannelli  
CERN





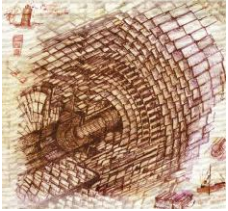
## The present CMS Silicon Tracker Inner Pixel Layers



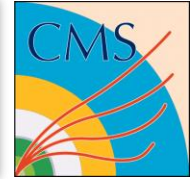
June 2009

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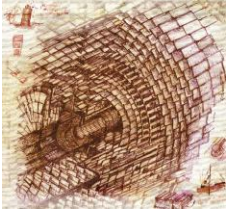
# The present CMS Silicon Tracker



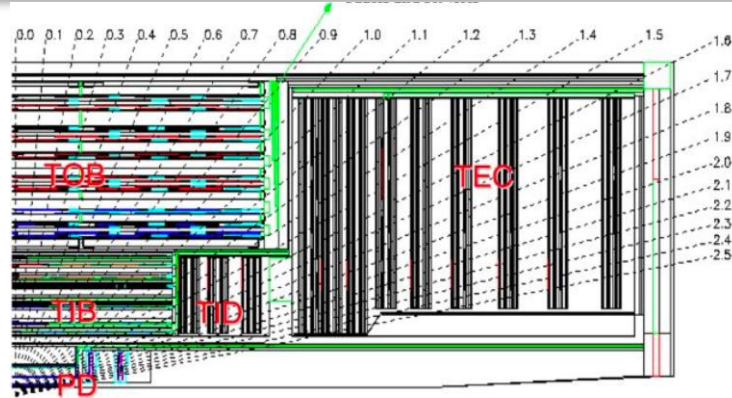
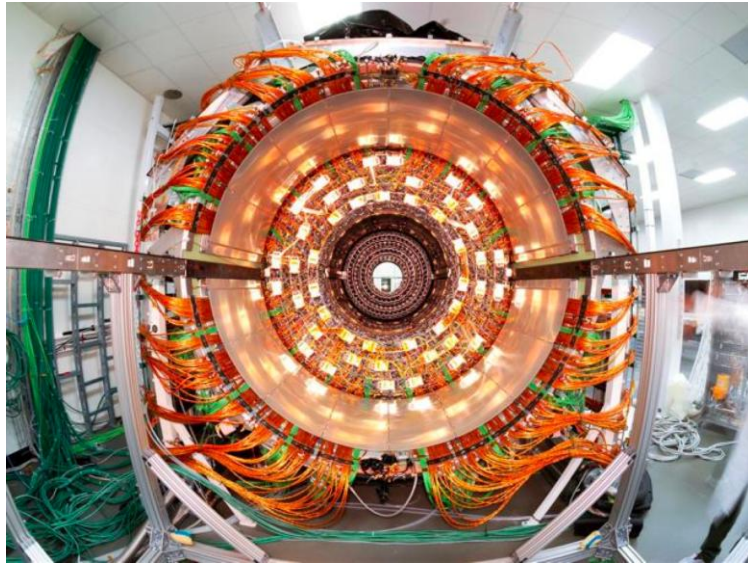
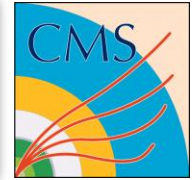
- **Inner Pixel Layers**

- **Scale: 3 layers ~ 1m<sup>2</sup>**
  - **Small production capacity required**
- **Radiation hardness up to  $6 \cdot 10^{14}$  1MeV neutron equivalent**
- **Double-sided process n-on-n, 4" wafers**
- **Thickness 280um**
- **Pixels of 100um \* 150um**
- **DC coupled, p-spray (barrel) p-stop (fwd) pixel isolation with bias provision**
- **Hybrid technology: Bump bonding to Front-End Electronics**
  - **Very high technological content**
- **High voltage operation & very low defect rate**
  - **Very stringent quality requirements**





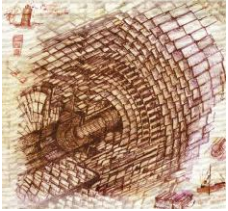
# The present CMS Silicon Tracker Silicon Strip Tracker



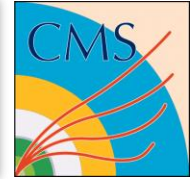
June 2009

The CMS All Silicon Tracker, Lessons Learned and  
Future Prospects

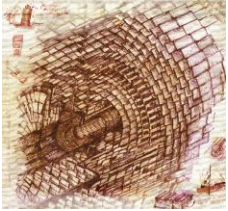
Marcello Mannelli  
CERN



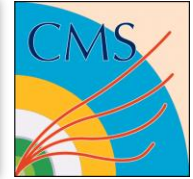
# The present CMS Silicon Tracker



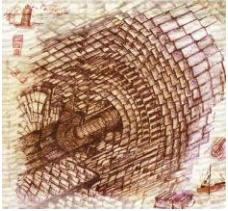
- **Silicon Strip Tracker:**
  - **Scale: largest of its kind, over 200m<sup>2</sup>**
    - **Very large scale production capacity required**
  - **Radiation hardness up to 1.6 / 0.5 \*10<sup>14</sup> 1MeV neutron equivalent**
  - **Single-sided process p-on-n, 6" wafers (sensors 80 ~ 90cm<sup>2</sup>)**
  - **320um / 500um thick**
  - **Strips of 80um ~ 240um \* ~ 9cm**
  - **AC coupled, Polysilicon biased**
  - **Hybrid technology: wire-bonding to Front-End Chip**
    - **High technological content**
  - **High voltage operation & very low defect rate**
    - **Very stringent quality requirements**



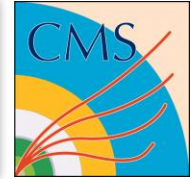
## The Present CMS Silicon Tracker



- **Two firms successfully contributed to sensor production for Inner Pixel Layers**
  - Both the successful suppliers had well established technological and quality assurance capability matching the requirements for the CMS Pixel sensor production
    - Procurements by Participating Institutes, with no CERN participation
- **One firm supplied ~ 98% of the CMS Tracker Silicon Strip sensors**
  - The successful supplier had well established high volume commercial production of many comparable products, matching the requirements for the CMS Strip Sensor production
  - Massive effort of CMS and Industrial Partners to establish a viable new production line for Silicon Strip Tracker was ultimately not successful
    - Procurement with broad Institute participation, centralized through CERN

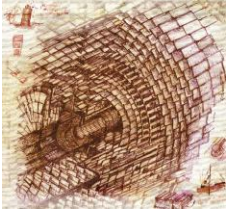


# The present CMS Silicon Tracker Lessons Learned

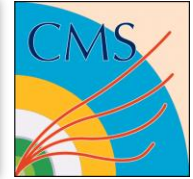


- **Crucial importance of correctly understanding required sensor characteristics and basic specifications**
  - **Goal of Targeted R&D**
  
- **Crucial importance of realistically matching well established production capability of candidate Industrial Partners to the requirements for**
  - **Technological Content, Quality Assurance, and Production Capacity**
    - All Tracker Sensors require a (very) high technological content, and very stringent quality criteria
    - The production capacity requirements for the Inner Pixel sensors and the Outer Tracker sensors are VERY different
  - **Is essential to avoid costly problems down the line**
    - For both the Project and the potential Industrial Partners
    - Want a Win-Win!
  - **Goal of Market Survey**



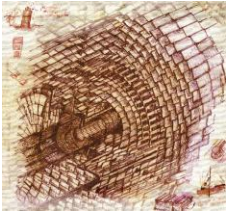


## The present CMS Silicon Tracker: Lessons Learned from Sensor Production

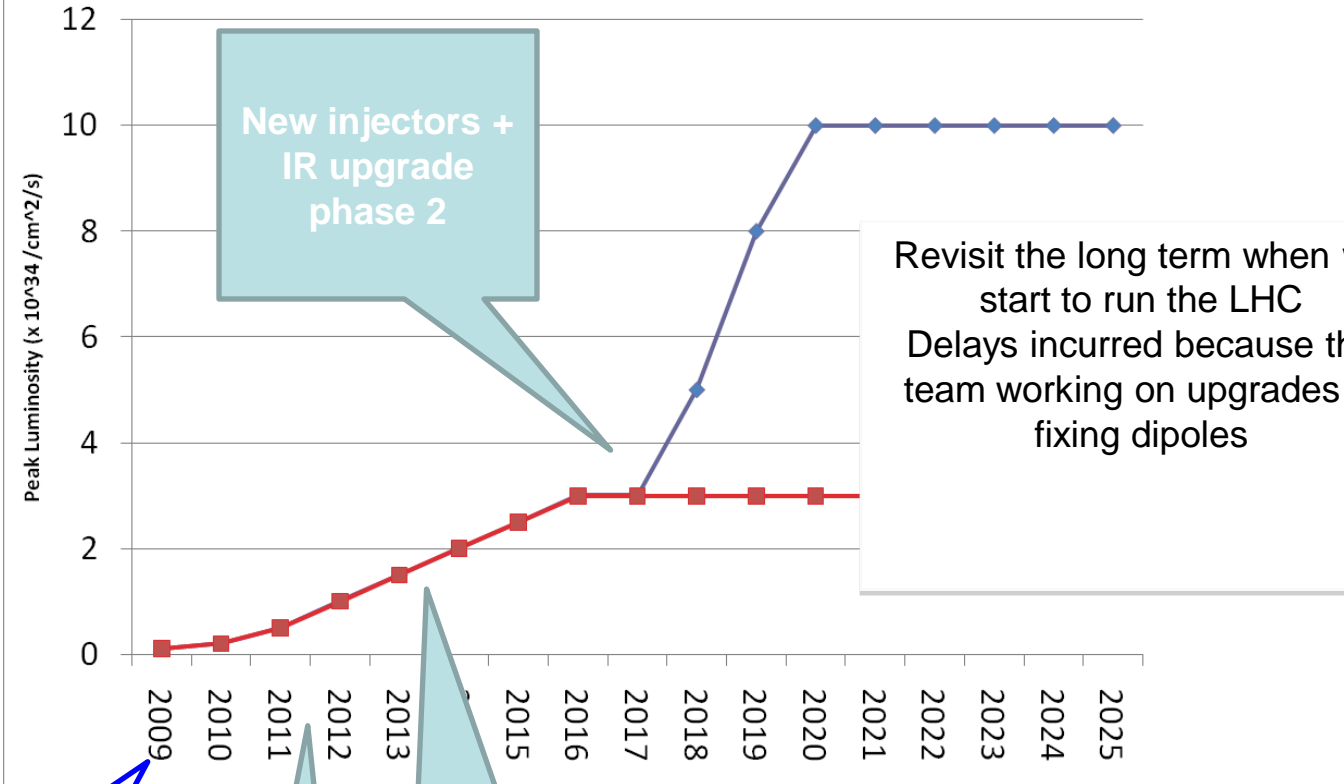
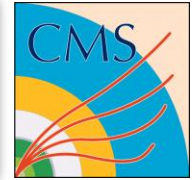


- **Crucial importance of design and process Optimization and Qualification for Production**
  - Is essential to lay the grounds for successful production
  - Goal of the Pre-Production and Qualification phase
- **Crucial importance of Homogeneity and Quality Assurance throughout entire Production**
  - Require identical sensors, all of equally excellent quality
  - Is essential to guarantee design functionality and reliability
  - Goal of Production phase





# Agreed Scenario for Peak luminosity (CMS/ATLAS/Machine/LHCC)



Revisit the long term when we start to run the LHC  
Delays incurred because the team working on upgrades is fixing dipoles

This schedule will be revised shortly to reflect situation after 3-4 incident

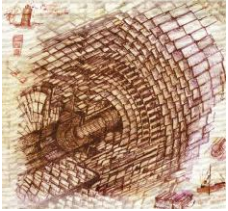
13 May 2009

Collimation phase 2

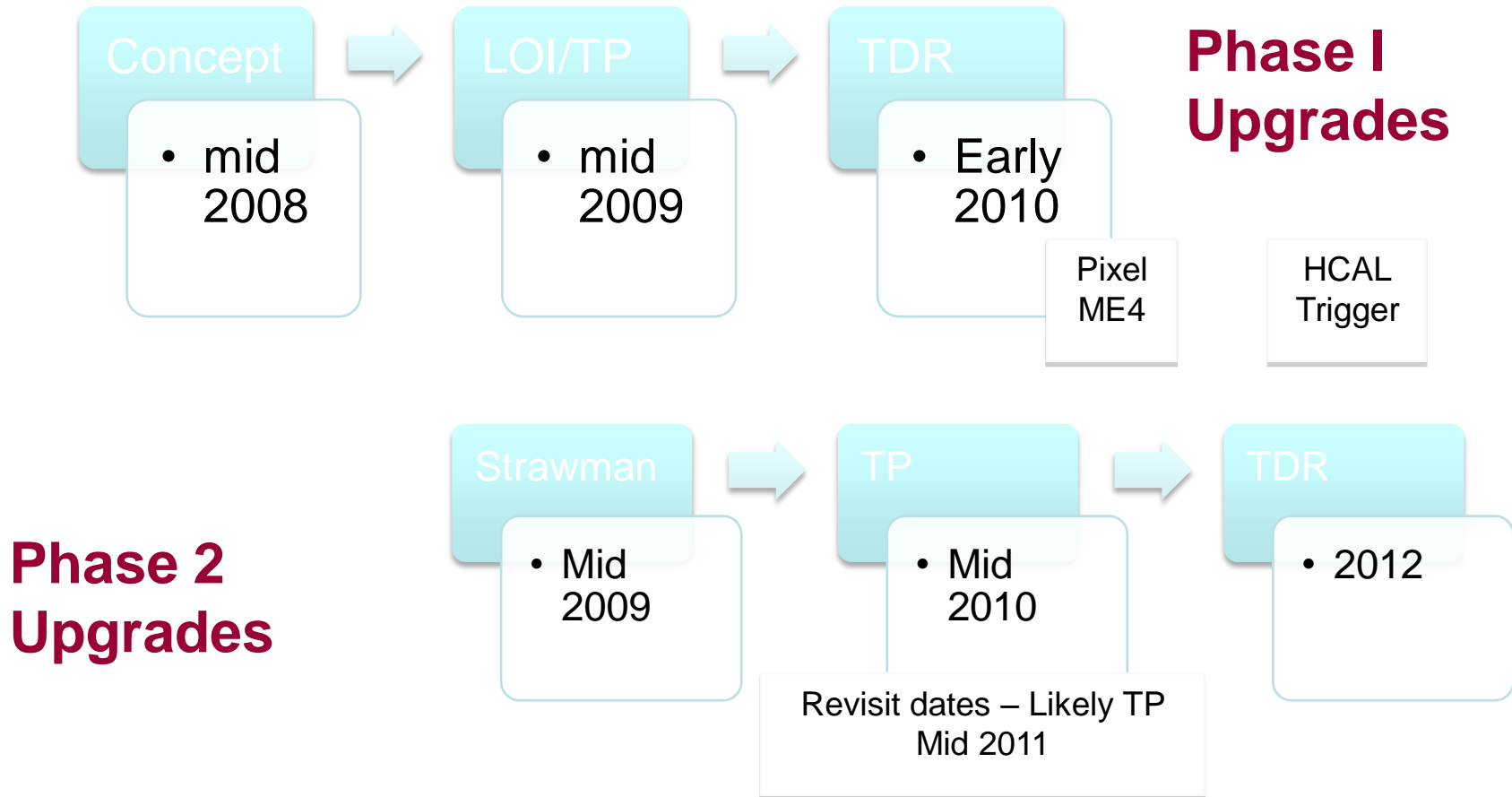
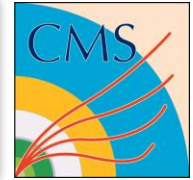
Linac4 + IR upgrade phase 1

J. Nash - CMS Upgrades

Marcello Mannelli  
CERN

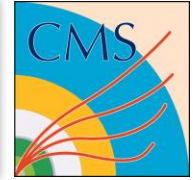


# Work Plan agreed at the May Workshop

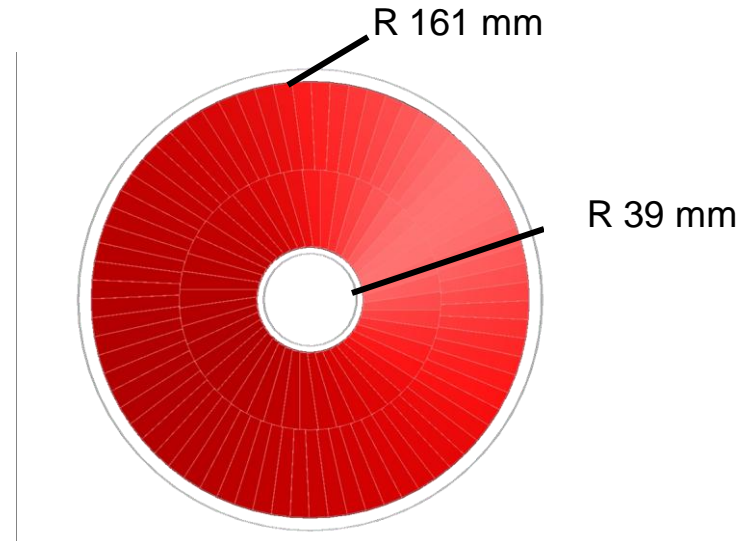
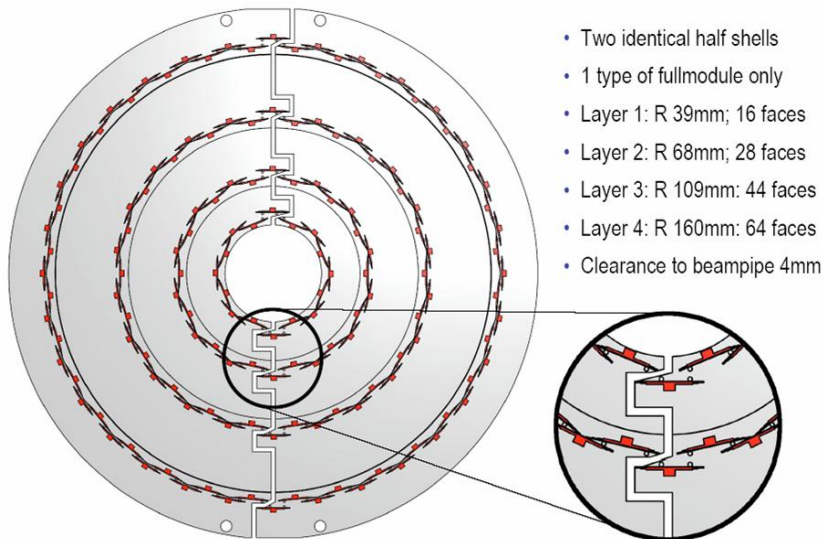




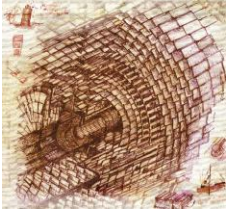
# Prospects for SLHC CMS Silicon Tracker: Inner Pixel Layers



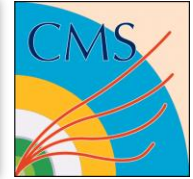
- **First Planned Upgrade: SLHC Phase I ~ 2013**
  - Barrel: from 3 layers to 4 layers (SLHC Phase I ~ 1.6 \* LHC)
  - End-Cap: from 2 \* 2 to 2 \* 3 larger discs (SLHC Phase I ~ 2.6 \* LHC)



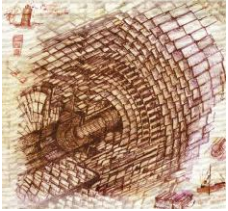




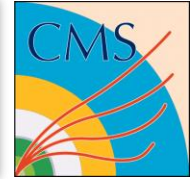
## Prospects for SLHC CMS Silicon Tracker: Inner Pixel Layers



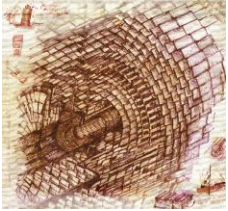
- **First Planned Upgrade ~ 2013**
  - **Scale: 4 barrel layers & 2 \* 3 End-Cap discs => ~ 2m<sup>2</sup>**
    - **Moderate production capacity required**
  - **Radiation hardness up to  $2 \cdot 10^{15}$  1MeV neutron equivalent**
  - **Single sided process n-on-n (n-on-p still possible?)**
  - **Thickness ~ 200um**
  - **Pixels of 100um \* 150um**
  - **DC coupled, pixel isolation and bias provision technology to be determined**
  - **Hybrid technology: Bump bonding to Front-End Electronics**
    - **Very high technological content**
  - **High voltage operation & very low defect rate**
    - **Very stringent quality requirements**



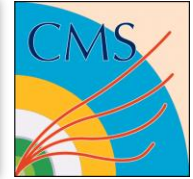
# Prospects for SLHC CMS Silicon Tracker: Inner Pixel Layers



- **Second Planned Upgrade ~ 2018**
  - **Scale: 4 ~ 5 layers => 2 ~ 4m<sup>2</sup>**
    - **Medium production capacity required**
  - **Radiation hardness up to  $6 \cdot 10^{15}$  1MeV neutron equivalent**
  - **Sensor type and Thickness to be determined**
    - Layers 2 and above n-on-p, < 200um thick ?
    - Layer 1 ?
  - **Pixels likely of 50um \* 100um**
  - **Hybrid technology: Bump bonding to Front-End Electronics**
    - **Very high technological content**
  - **High voltage operation and very low defect rate**
    - **Very stringent quality requirements**
- **Further Possible Upgrade ~ 2023 ?**

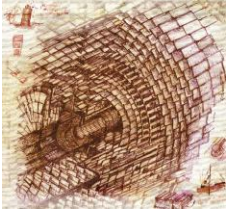


# Prospects for SLHC CMS Silicon Tracker: Tracking Trigger & Tracking Layers ~ 2018

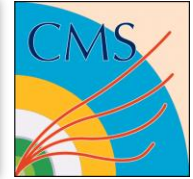


- **Scale: Number of layers to be determined => 150m<sup>2</sup> ~ 250m<sup>2</sup>**
  - **Very large production capacity required**
  
- **Radiation hardness up to 1.6\*10<sup>15</sup> 1MeV neutron equivalent**
- **Sensor type and Thickness to be determined**
  - Single sided process thin p-on-n ok at larger radii
  - Ok also at smaller radii, or need or n-on-p ?
- **Tracking Trigger Layers Pixels**
  - Pixels likely ~ 100um \* 1 ~ 2mm; DC coupled, biasing scheme tbd
- **Other Tracking Layers Strips**
  - Strips likely 100um \* 2cm ~ 4cm; Strip coupling & biasing scheme tbd
- **Hybrid technology: bonding to Front-End Electronics to be determined**
  - Vertical Integration of modules: "stacked" pair of closely spaced sensors
    - **(Very) high technology content**
  
- **High voltage operation and very low defect rate**
  - **Very stringent quality requirements**





## Prospects for SLHC CMS Silicon Tracker: Tracking Trigger & Tracking Layers



- **Preparatory Phase: Targeted R&D** ~ 2008 - 2012
  - Establish required sensors characteristics & basic specifications
  - Comparative Study of “thin” p-on-n and n-on-p on FZ. MCZ & Epi material
- **Phase A: Preproduction and Qualification** ~ 2012 - 2014
  - Finalize detailed specifications and QA protocols
  - Qualify for large scale production
- **Phase B: Large Scale Production** ~ 2014 - 2016
- **Market Survey to identify Industrial Partners for Phases A and B**
  - Producers qualified according to this MS may take part in Phase A
  - Qualification for Phase B is contingent on Phase A success