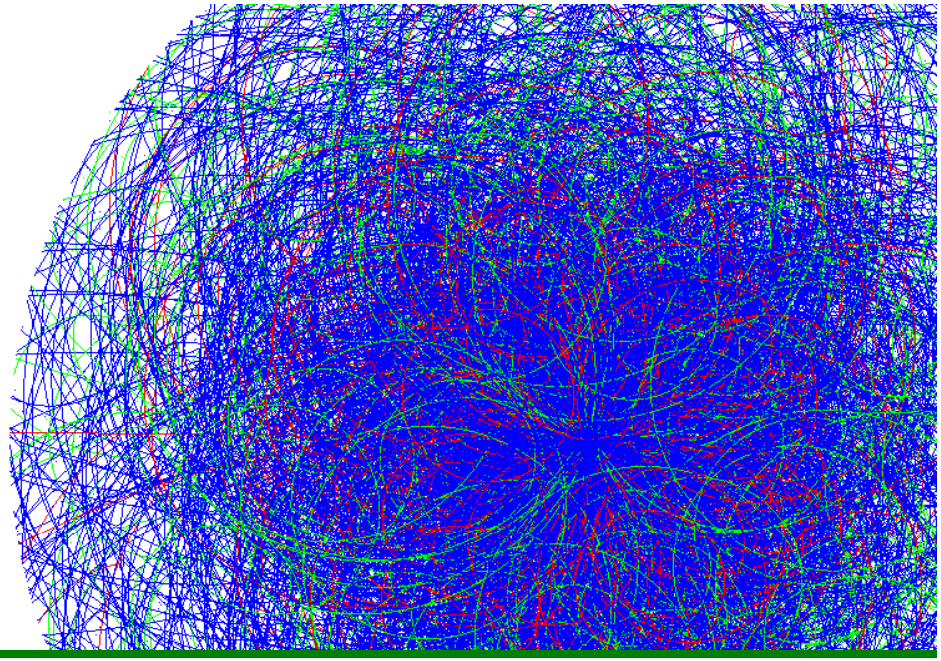

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Upgrading the CMS Tracker for SLHC

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Outline

The CMS Detector

What is the SLHC proposal?

How will CMS upgrade its detector?

CMS tracker and trigger ideas for SLHC

The CMS Detector – Tracker & Readout

High radiation levels in central region.

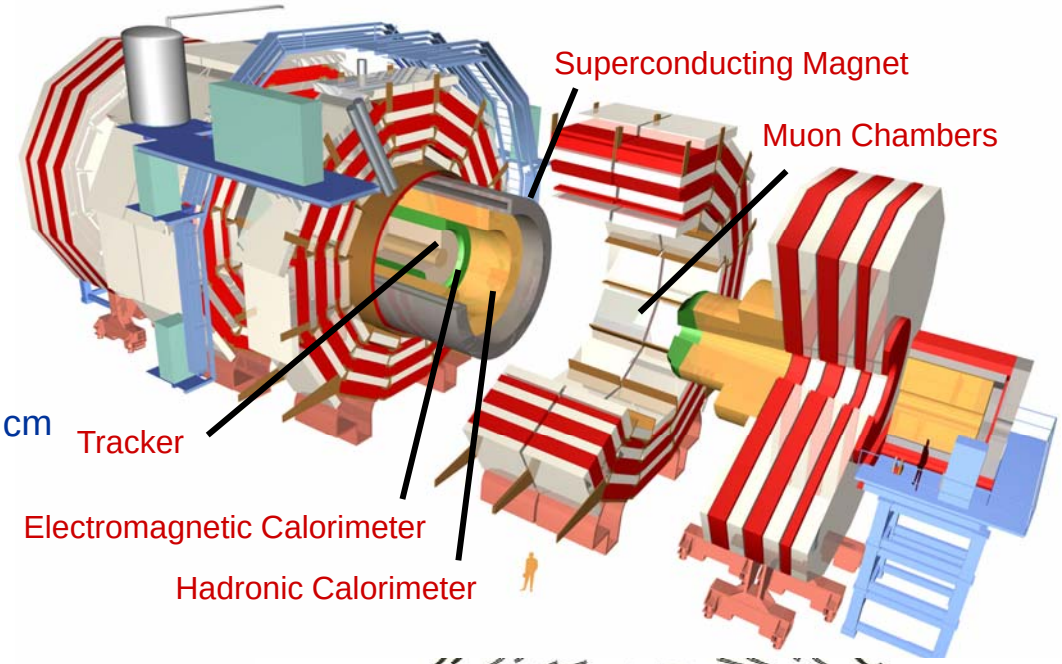
After 10 years of LHC operation,

32 x 10^{14} cm^{-2} fast hadron fluence @ r=4 cm

840 kGy (84 Mrad) radiation dose @ r=4 cm

High charged particle flux

1.65 x 10^{8} $cm^{-2}s^{-1}$ @ 10^{34} $cm^{-2}s^{-1}$ luminosity, r=4 cm



Silicon Strip Tracker

10 million microstrip readout channels

200m^2 of active silicon area

R-phi point resolutions ~ 20-50 μm in barrel region

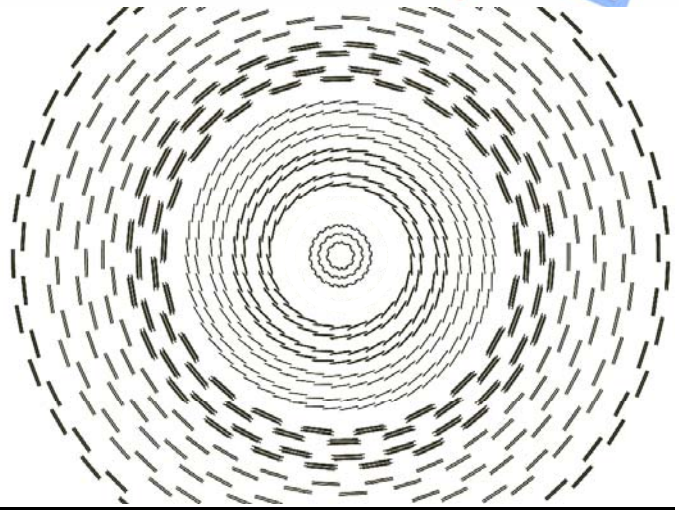
Full analogue readout of 25 ns crossings @ 100 kHz

Pixel Detector

66 million pixel readout channels

Point resolutions ~10 μm in r-phi, 15-20 μm in z

Zero-suppressed analogue readout @ 100 kHz



The SLHC Proposal

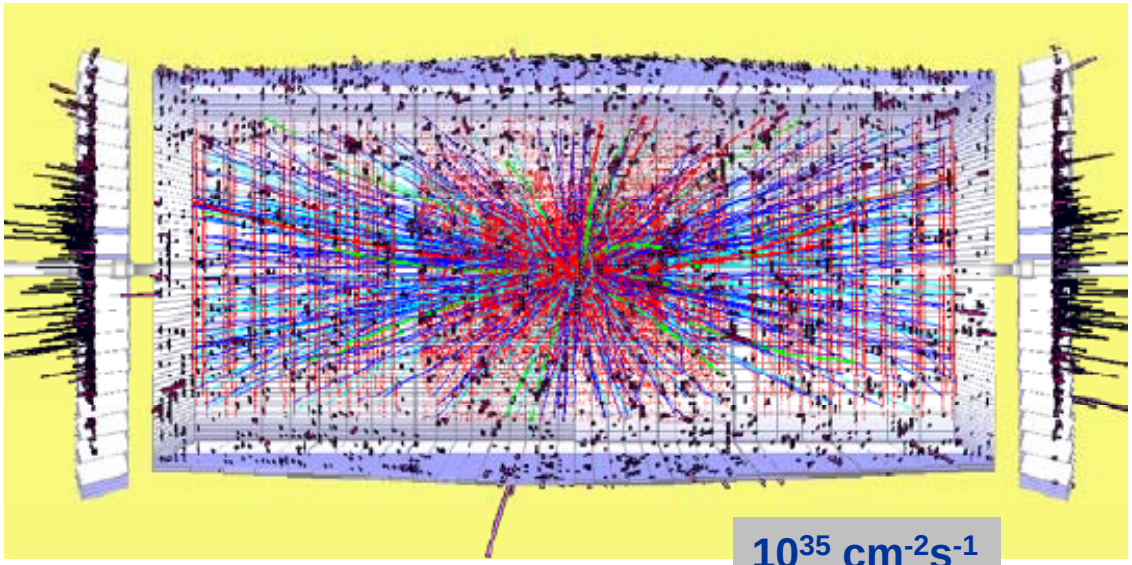
Current proposal to increase luminosity of the LHC machine to 10^{35} $cm^{-2}s^{-1}$ by 2018

Plan to achieve this in 2 stages:

Phase I - increase machine luminosity to 2 x 10^{34} $cm^{-2}s^{-1}$ in 2013

Phase II - increase machine luminosity to 1 x 10^{35} $cm^{-2}s^{-1}$ in 2018

- Plan to decrease bunch crossing rate from 40 MHz to 20 MHz . Peak interactions per event to increase from 20 at design luminosity to 400 in a worst case scenario



CMS Upgrade Plan

Most of the outer CMS detector would be able to cope with the proposed increases in luminosity

Muon Chambers – OK, possible replacement to triggering chambers (RPCs) required at high eta (>1.6)

ECAL – OK, replacement of the endcap electronics may be required

HCAL – OK, Forward HCAL (HF) at high eta would benefit from replacing

Strip Tracker – Will have reached the end of its 10 year lifespan and would benefit from an upgrade for Phase II

Pixel Detector – Some layers will need to be replaced for Phase I, a total upgrade will be required for Phase II

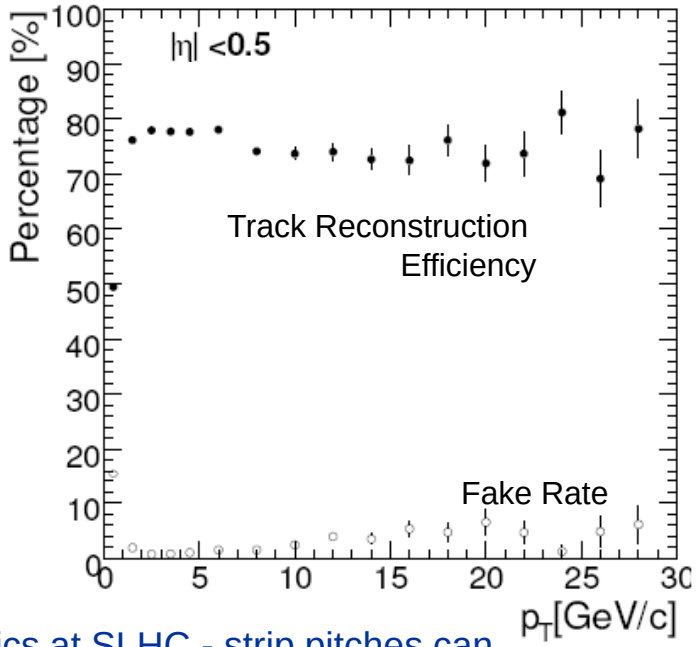
Trigger – Upgrade of off detector trigger electronics at L1, 100 kHz output rate is to stay the same, L1 Latency can increase from 3.2 μs to 6.4 μs

Issues with a CMS Tracker at SLHC

A new tracker must be able with this highly congested and hostile environment and yet maintain or improve the physics performance of the detector

Simulation studies with heavy ions at the LHC† have shown that at CMS, high track reconstruction efficiency can be maintained while keeping fake track rates low

- This is despite occupancies ~20-30% in the inner strip tracker compared to 2-3% for p-p collisions at design luminosity
- SLHC occupancies may be a factor of two larger



Tracker granularity may be increased

- Current spatial and momentum resolutions are sufficient for physics at SLHC - strip pitches can be maintained (80-120 um)
- Occupancy may be reduced by decreasing strip lengths or by using pixel layers in the intermediate tracking regions
- Pixel dimensions may be maintained – occupancy increase to 1-2% is manageable

†C. Roland, *Track Reconstruction in Heavy Ion Events using the CMS Tracker*

Issues with a CMS Tracker at SLHC

A reduction in material budget would benefit CMS

- Would reduce photon conversion, bremsstrahlung and multiple scattering
- Most of the current tracker material is electronics related – including cooling and cabling
- Will be a challenge just to maintain present material budget

Power & Cooling in the tracker will be a significant problem

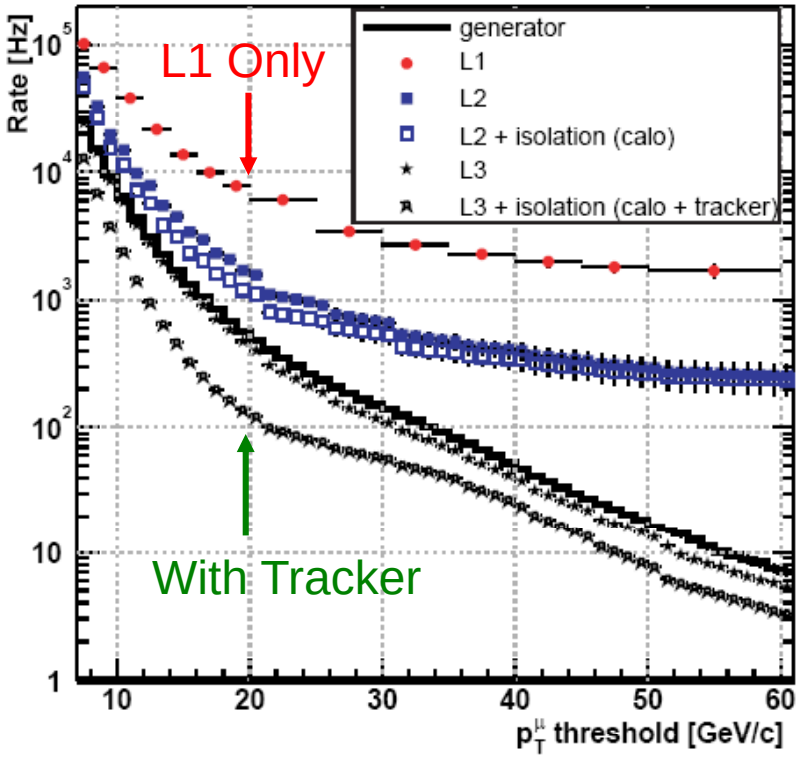
- Heat loads in the cables will increase due to the greater current drawn by the front end – requiring cooling
- Greater radiation damage will increase leakage currents
- Increasing the granularity of the tracker will also increase FE power

High particle fluences and radiation doses mean that new rad hard sensor technologies are required in the inner regions ($r < 20$cm)

Issues with a L1 Trigger at SLHC

Triggering at SLHC will be extremely difficult due to increased occupancies, backgrounds and pile up

- Efficiencies and purities will fall
- Increasing calorimetric thresholds to maintain the L1 rate is not acceptable – scale is set by W/Z/H masses
- Muon pt threshold cut has no rejection power above p_t > ~20 GeV/c

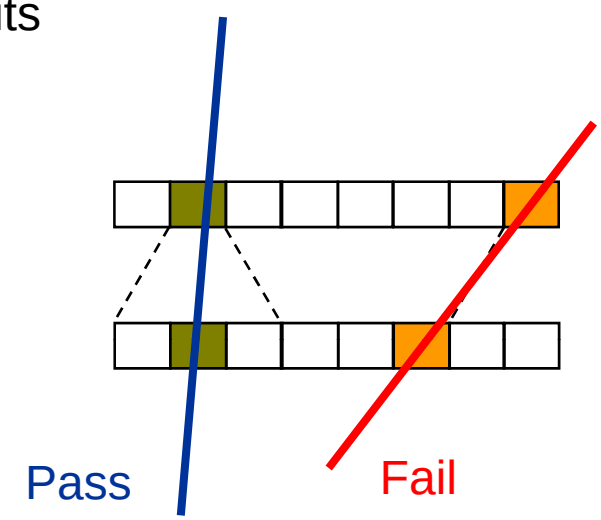


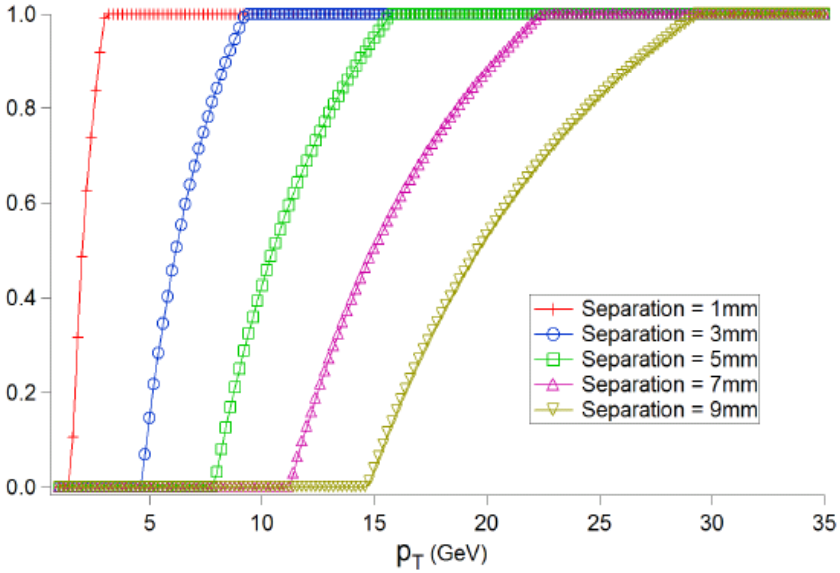
Solution is to include some form of tracking information at L1 in a similar way as it is used in the High Level Trigger

Stacked Tracking

Closely spaced pixel sensors can provide a geometrical cut on the pt of a crossing track by checking neighbouring pixels for hits

- Could be used as part of a L1 trigger decision
- Can be used as a local occupancy reduction method
- Two or more layers can be used to calculate the track p_t



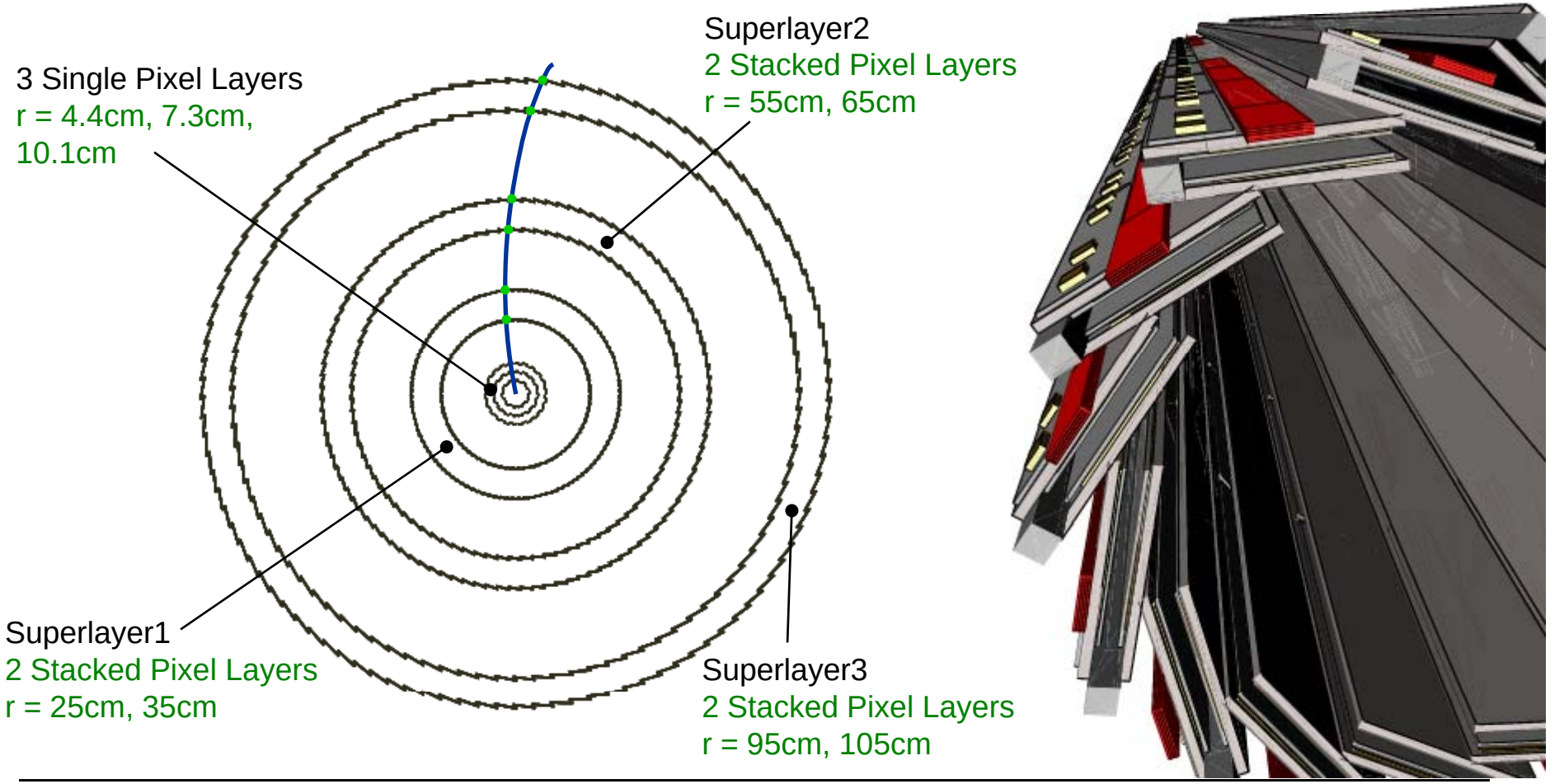


J. Jones, C. Foudas, A. Rose

- *A Study of a Tracking Trigger at First Level for CMS at SLHC*
- *Stacked Tracking for CMS at Super-LHC*

Simulation of Tracker Geometries

Various geometries are being constructed and tested within the CMS software framework using GEANT to simulate the tracker performance



Summary

The LHC will be upgraded to achieve a luminosity of at SLHC

The environment at SLHC will be extremely challenging

Up to 400 interactions per bunch crossing

CMS Tracker will need to be upgraded

- Issues with granularity, power, cooling, material budget, data rates, sensor radiation tolerance

Level 1 Trigger will need to be upgraded

- Tracker information is needed – Stacked Tracking may help at L1

Simulations of different geometries and ways of including stacked tracking are ongoing