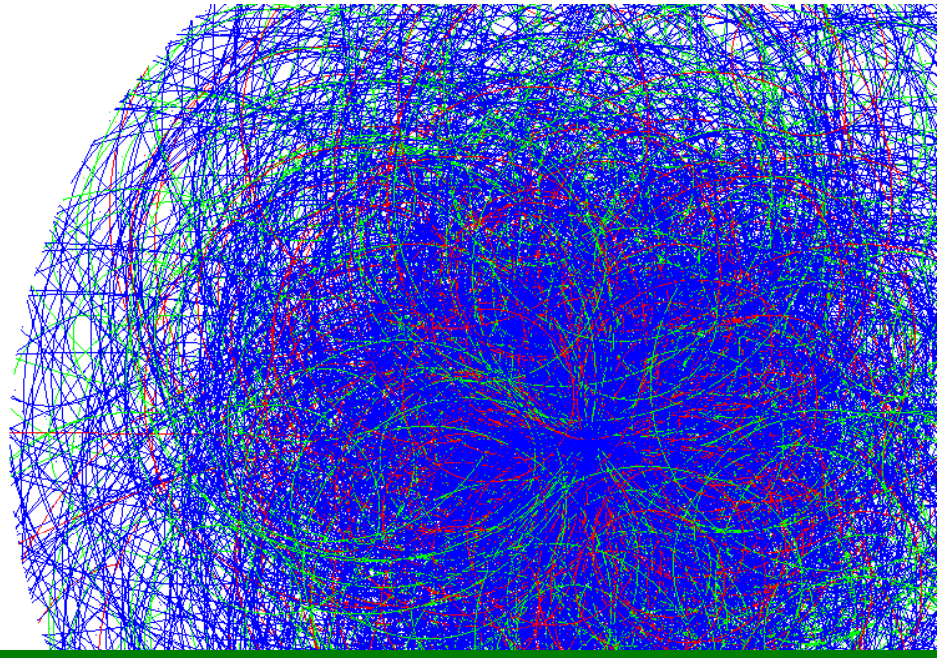

IOP HEPP Conference 2008
31.3.08

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.

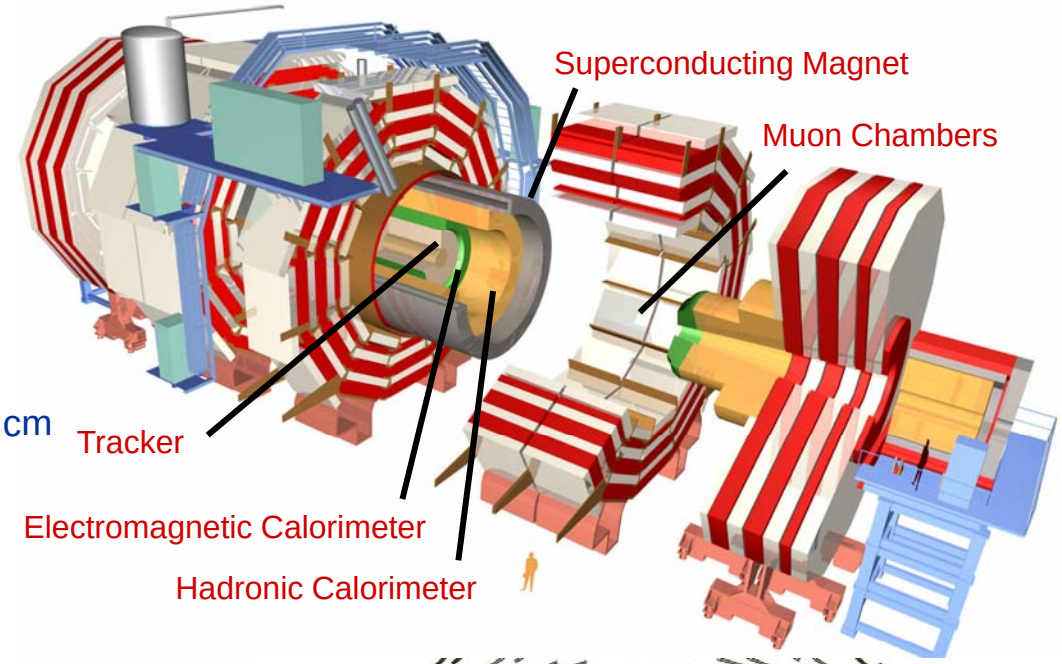
After 10 years of LHC operation,

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

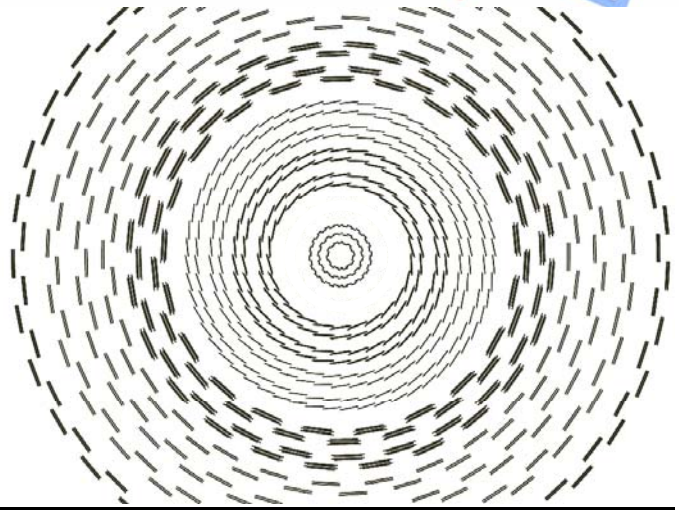
Full analogue readout of 25 ns crossings @ 100 kHz

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



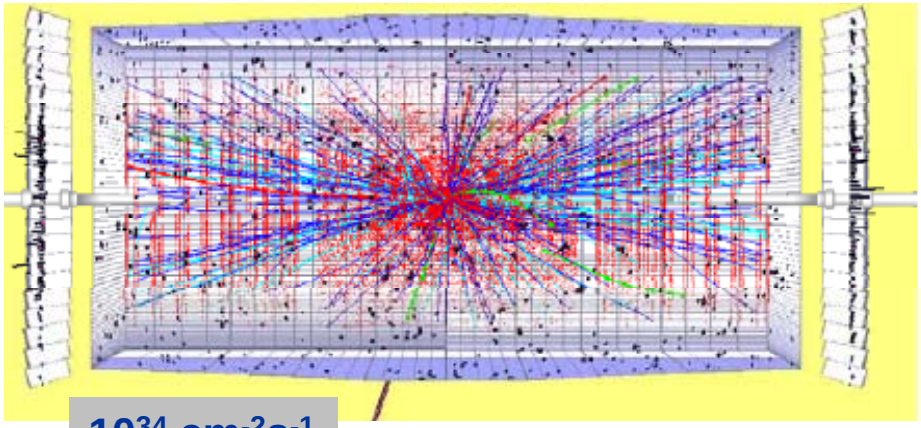
The SLHC Proposal

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:

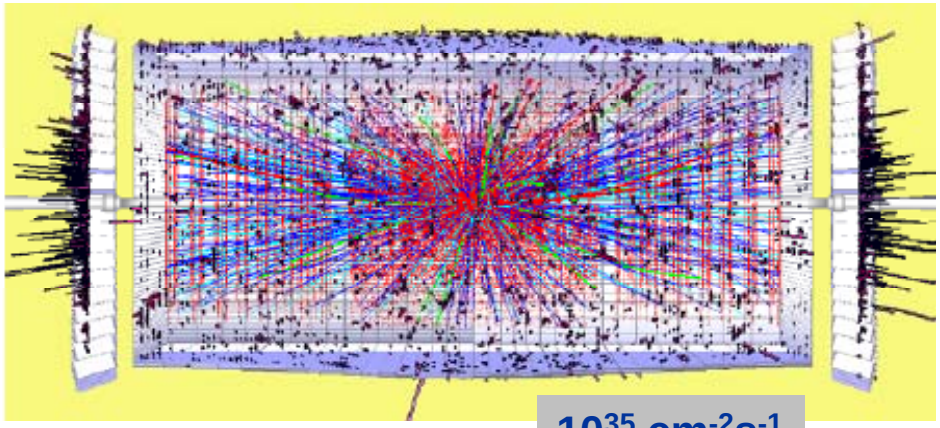
Phase I - increase machine luminosity to 2 x 10^{34} $cm^{-2}s^{-1}$ in 2013

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



10^{34} $cm^{-2}s^{-1}$

CMS Tracker and ECAL at Peak LHC Luminosity
~20 interactions/bunch crossing



10^{35} $cm^{-2}s^{-1}$

CMS Tracker and ECAL at Proposed SLHC Luminosity
~300-400 interactions/bunch crossing

CMS Upgrade Plan

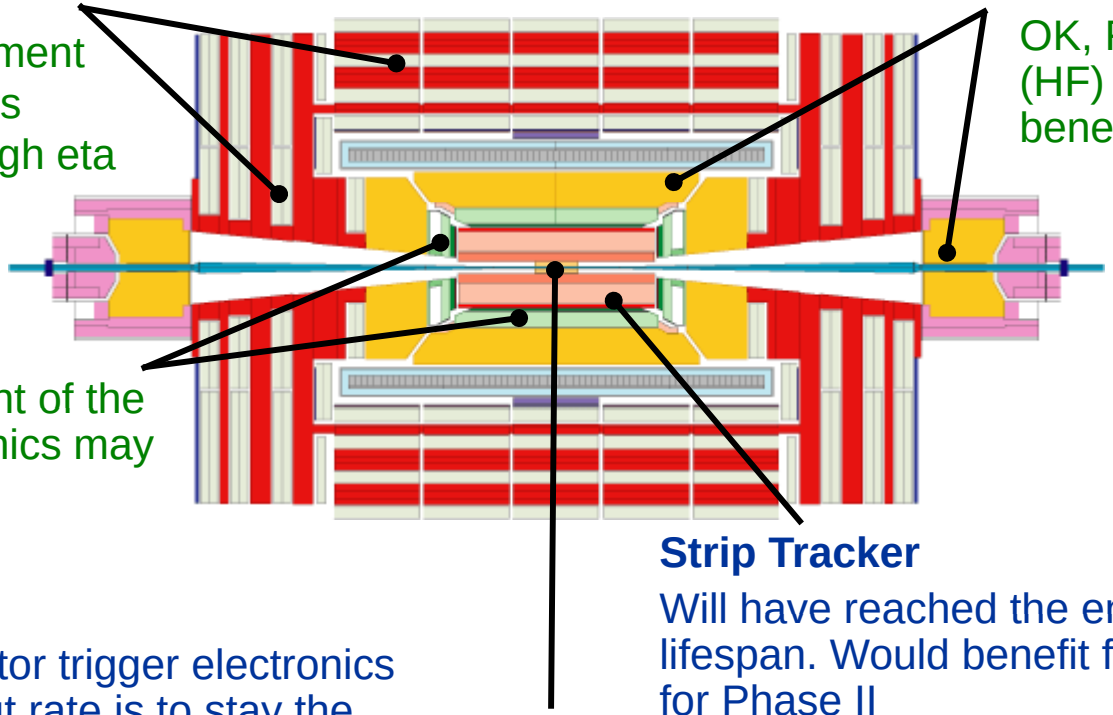
Most of the outer CMS detector would be able to cope with the proposed increases in luminosity

Muon Chambers

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

HCAL

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



ECAL

OK, replacement of the endcap electronics may be required

Strip Tracker

Will have reached the end of its 10 year lifespan. Would benefit from an upgrade 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 ms to 6.4 μs

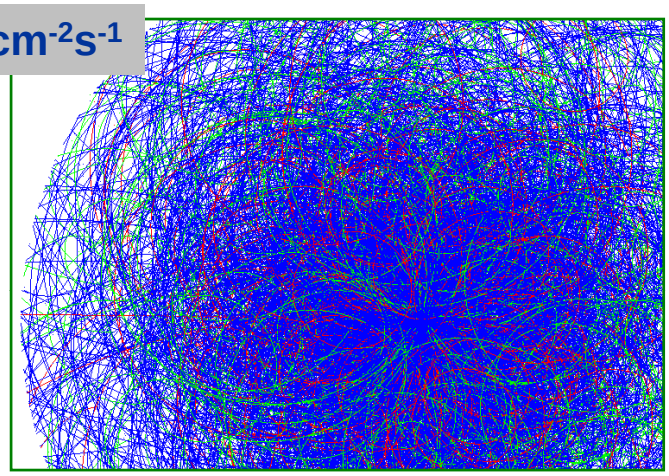
Pixel Detector

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

SLHC Tracker – The Challenges

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

Tracking



Can we still do tracking at 10^{35} cm^{-2}s^{-1} ?!

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 despite 10x greater occupancies. A good start!

To improve on this, we can lower the occupancy

Current spatial and momentum resolutions are sufficient for physics at SLHC - strip pitches can be maintained (80-120 μm)

Reduce occupancy by decreasing strip lengths or by using pixel layers in the intermediate tracker regions

Radiation Damage & Sensor Technology

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

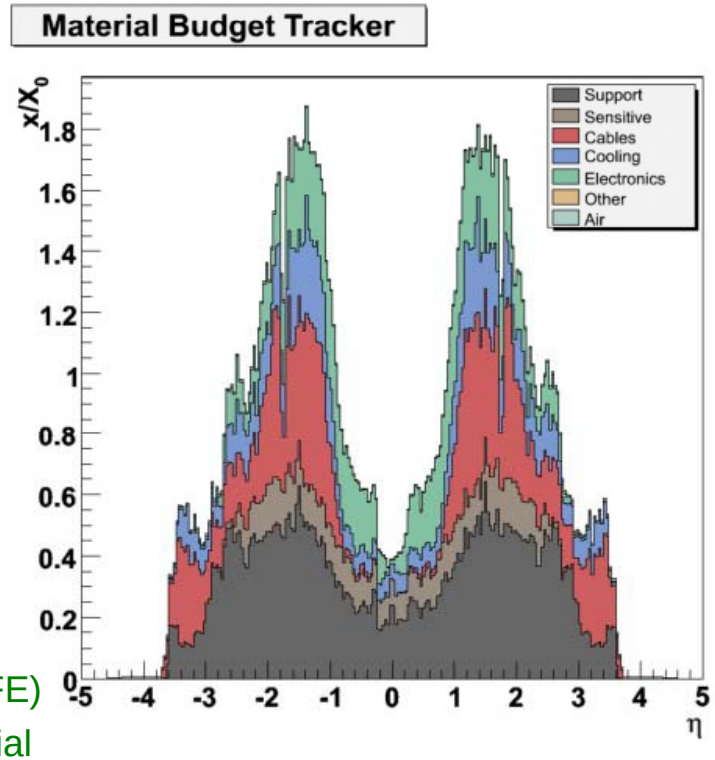
SLHC Tracker – The Challenges

Material

We would like to reduce material in the tracker to reduce photon conversions, 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

Will be a huge challenge to deliver power to the Tracker Front End (FE) as well as to remove the heat produced without increasing the material

Tracker already draws almost as much current as the CMS 4 Tesla superconducting magnet does!!

Heat loads in the cables will increase due to the greater current drawn by the front end – requiring cooling

Greater sensor radiation damage will increase leakage currents and increasing the granularity of the tracker will also increase FE power

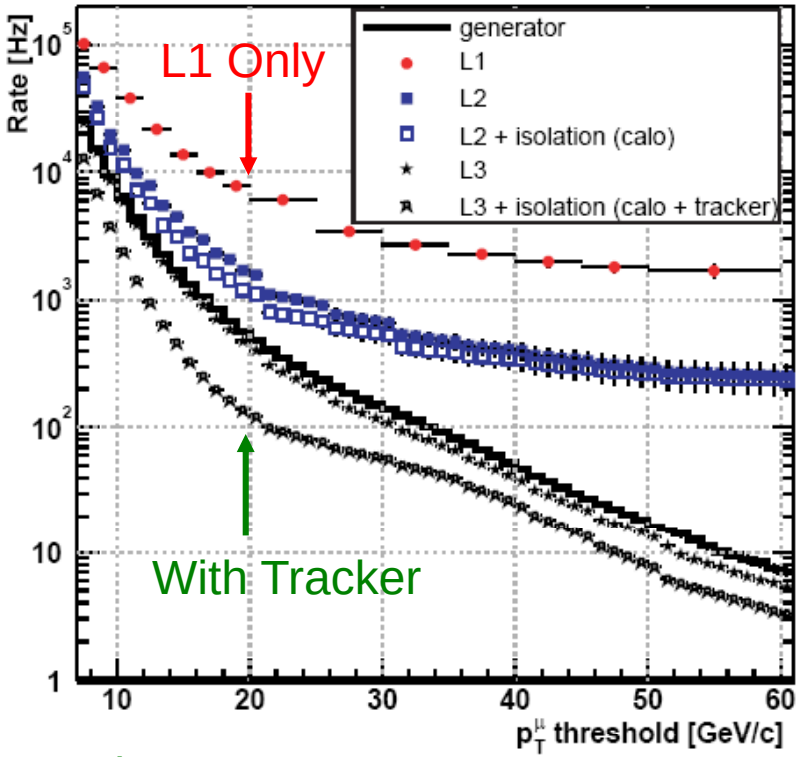
Issues with a L1 Trigger at SLHC

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



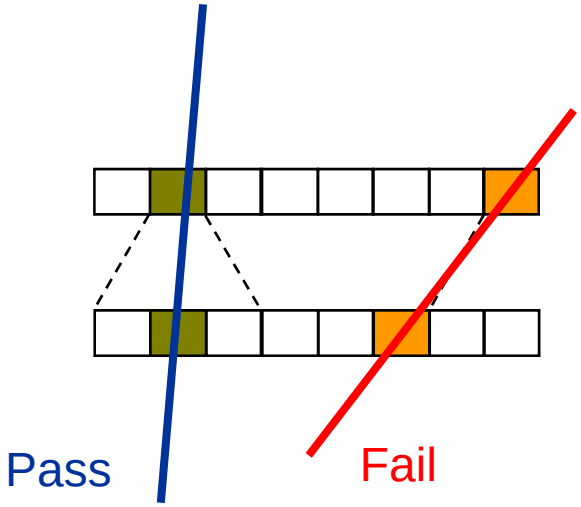
Solution is to include some form of tracking information at L1 in a similar way as it is used in the High Level Trigger

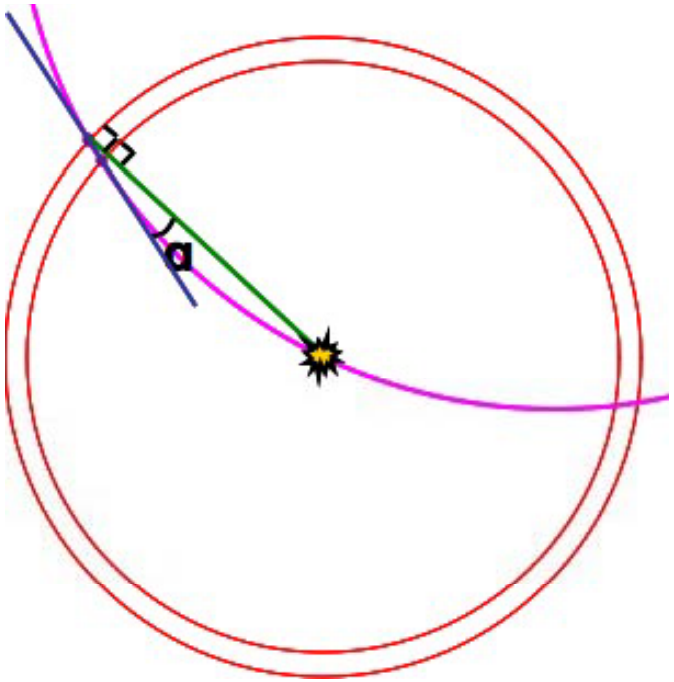
Challenge to get the data off detector for hardware trigger decisions

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

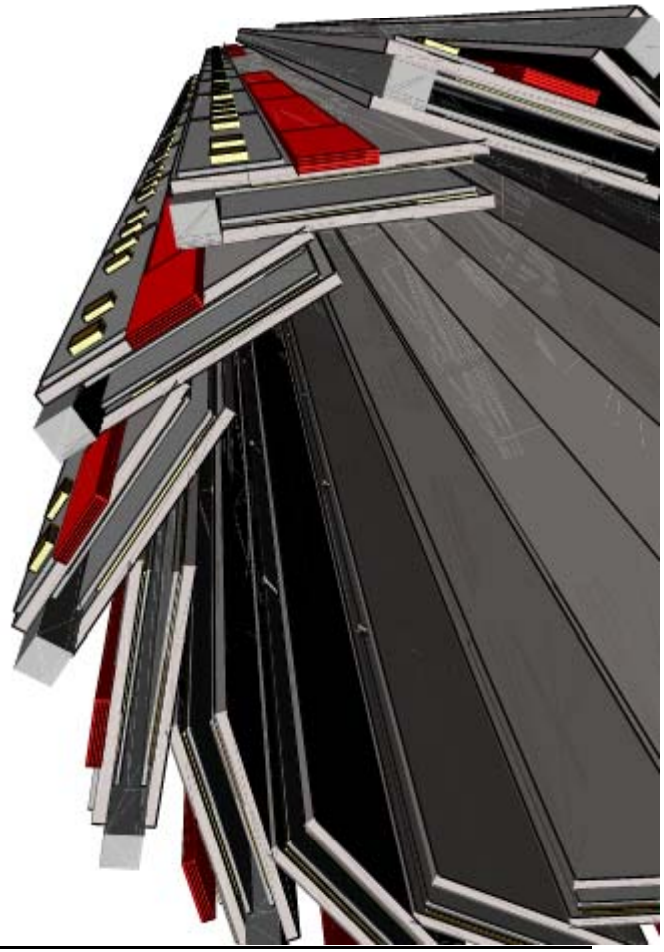
- *A Study of a Tracking Trigger at First Level for CMS at SLHC*
- *Stacked Tracking for CMS at Super-LHC*

Simulation of Tracker Geometries

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

Many difficulties….

- Event simulation takes too long at SLHC luminosity. More than 250 min/event!!
- Re-simulation required for every change in detector specification
- Reconstruction software not specifically designed for changes to the detector geometry – work is only just starting on configurability

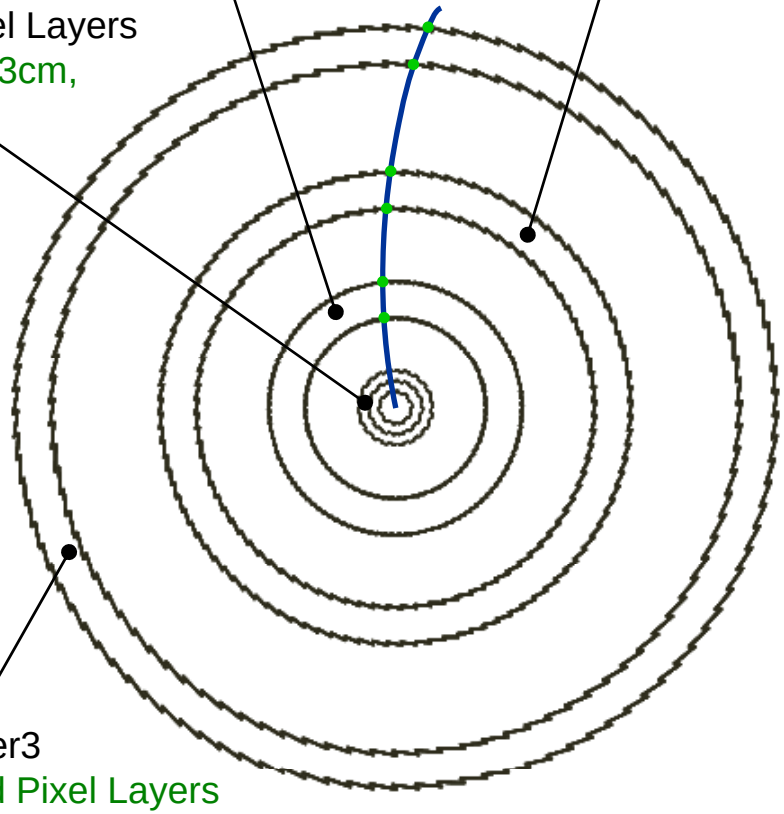


Simulation of Tracker Geometries

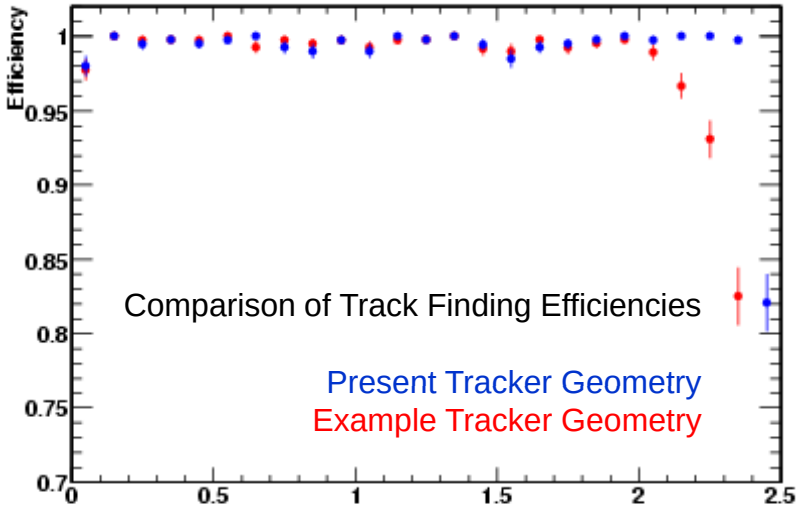
Superlayer2
2 Stacked Pixel Layers
r = 55cm, 65cm

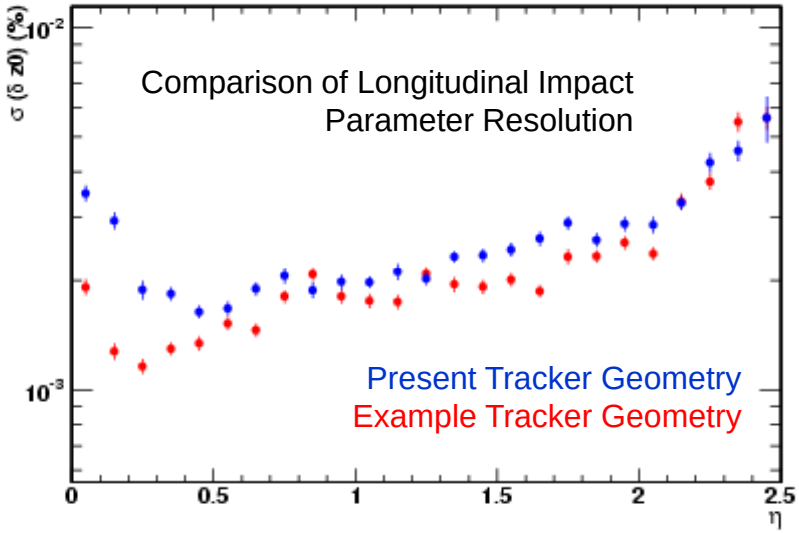
Superlayer1
2 Stacked Pixel Layers
r = 25cm, 35cm

3 Single Pixel Layers
r = 4.4cm, 7.3cm,
10.1cm



Superlayer3
2 Stacked Pixel Layers
r = 95cm, 105cm





Summary

The LHC will be upgraded to achieve a luminosity of 10^{35} $cm^{-2}s^{-1}$ 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, cost

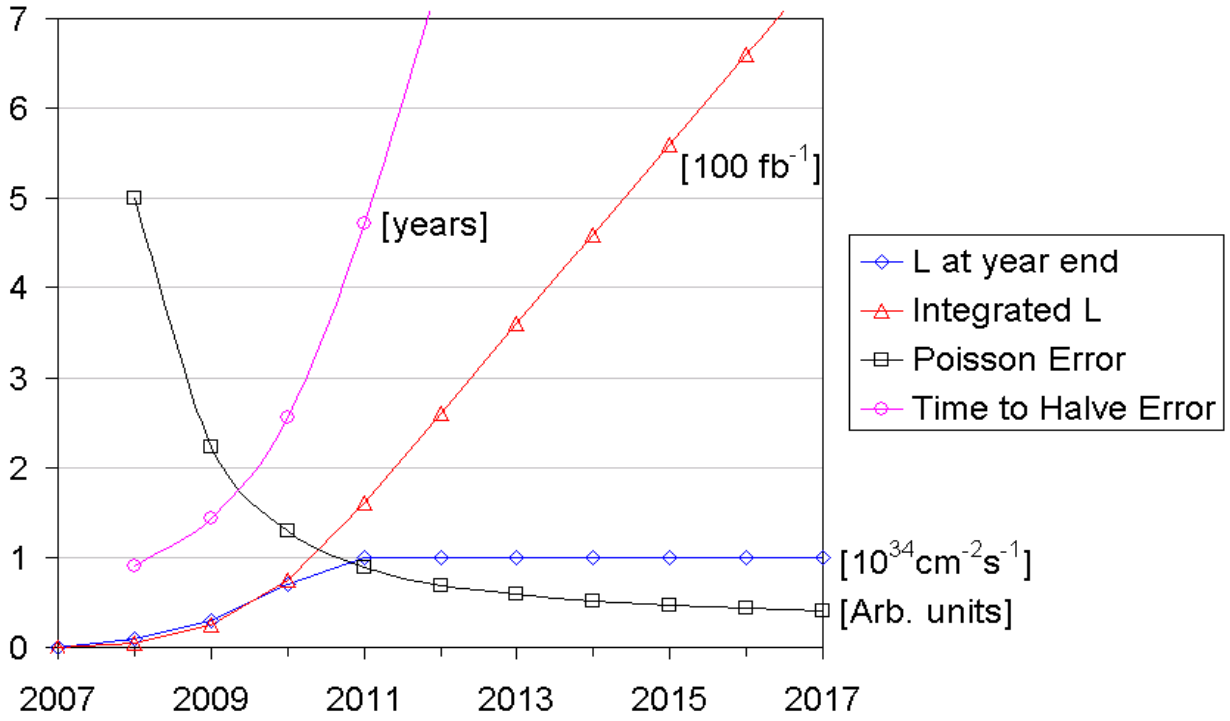
Level 1 Trigger will need to be upgraded

Tracker information is needed – Stacked Tracking may help at L1

Simulations of different geometries and ways of including stacked tracking are just starting but much more work remains ahead of us. We expect to publish a TDR in 2012

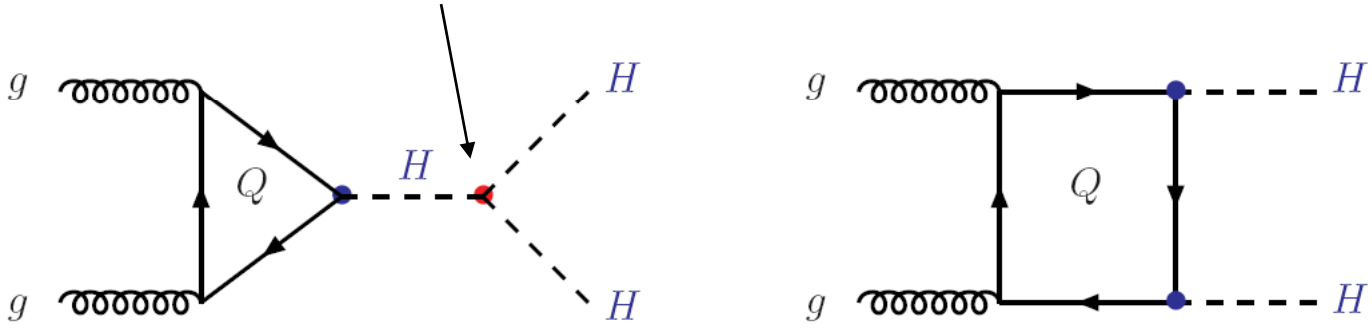
Backup

LHC Luminosity vs. Time



Higgs at SLHC

- Whatever Higgs variant is discovered, more information on its properties than LHC can provide will be needed to establish a better understanding of the underlying physics.
  λ accessible by trilinear coupling measurement



- Expected HH production after all cuts in 4W -> $l^{+/-}l^{+/-}$ + 4j mode
  σ = 0.07 - 0.18fb for m_H = 150 - 200 GeV
- with 3000fb^{-1} => ~200-600 signal events
  + significant background
- Rare Higgs decays such as H -> $\mu\,\mu$, H -> Z γ , can be detected at the SLHC