CMS Detector Upgrades

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SLHC Detector Environment

	LHC	SLHC
$\sqrt{s}$	14 TeV	14 TeV
L	10^{34} $/(cm^2 \cdot \sec)$	10^{35} $/(cm^2 \cdot \sec)$
$\int Ldt$	100 fb^{-1}/yr	1000 fb^{-1}/yr
Bunch spacing dt	25 ns	12.5 ns
N. interactions/x-ing	~ 12	~ 62
$dN_{ch}/d\eta$ per x-ing	~ 75	~ 375
Tracker occupancy	1	5
Pile-up noise	1	~2.2
Dose central region	1	10

Bunch spacing reduced 2x. Interactions/crossing increased 5 x. Pileup noise increased by 2.2x if crossings are time resolvable.

Upgraded Detectors

- **The existing trackers will not be capable of utilizing the increased luminosity as they will be near the end of their useful life.**
- **It is necessary to completely rebuild the LHC tracking detectors.**
- **Calorimeters will survive except for highest η of central calorimeter. Need new developments here.**
- **Muon System probably OK. Need enhanced triggering.**

Tracker - Occupancy

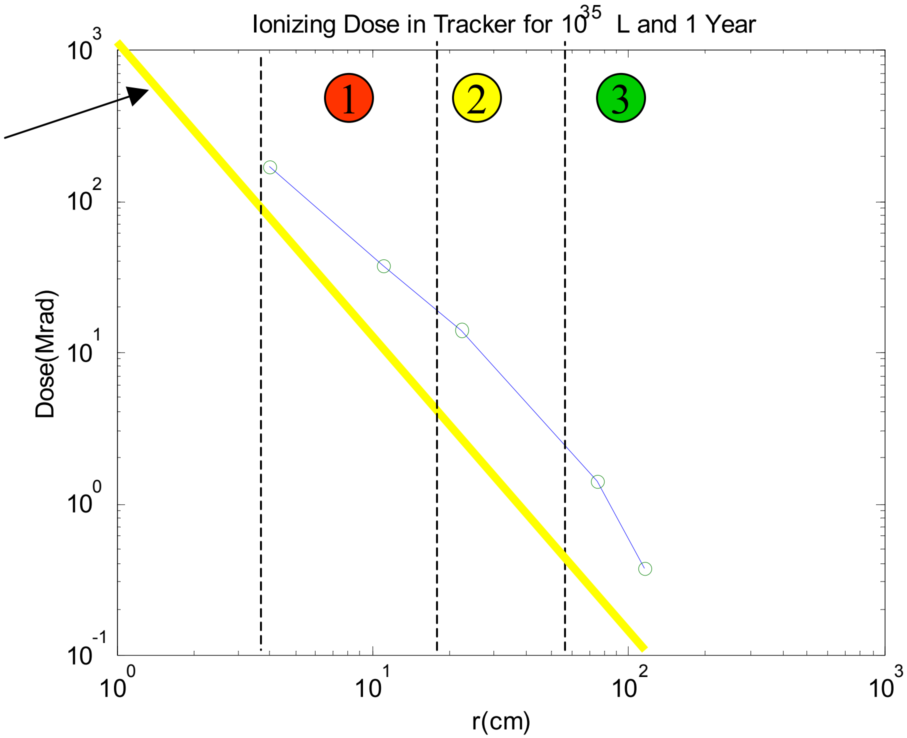
- **The occupancy, O, for a detector of area dA and sensitive time time dt at (r,z) is**

$$O = \ell \sigma_I \rho_c (dAdt)/[2\pi r^2]$$

- **For higher luminosity, decrease dA, or decrease dt (limit is x-ing time) or increase r – smaller, faster or further away.**

Tracker Dose vs Radius

naive



Define 3 regions. With 10x increase in L, need a ~ 3x change in radius to preserve an existing technology.

Tracker Occupancy

- Preserve the performance using $1/r^2$:
  - Push Si strips out to ~ 60 cm. – development
  - Push pixels out to 20 cm. – development
  - For r < 20 cm. Need new technologies – basic research
- Shrink dA 5x at fixed r
  - If 12.5 nsec bunchx, need 5x pixel size reduction.
- Possibilities
  - 3-d detectors – electrodes in bulk columns
  - Diamond (RD42) - radhard
  - Cryogenic (RD39) – fast, radhard
  - Monolithic – reduced source capacity.

SLHC Tracking Development Project RD50

- Approved by CERN 06/02
- 52 institutions, 5 from US (Fermilab, Purdue, Rutgers, Syracuse, BNL), 2 interested to join UCSB, UR
- Areas of research
  - Material engineering
    - Oxygenation, si carbite
  - Device engineering
    - Pad, 3D, thin detectors
  - Rad hard technologies used for LHC are not completely characterized

Interesting New Material – CVD Diamond

- New Process creates mono-crystal diamond wafers. (Apollo Diamond, www.apollodiamond.com)
- Wafer size currently ~ 1X1 inch
- Target wafer size 4X4 inches
- Fabrication cost ~ $5 /carat (1 carat = 0.2 grams) → 250 micron * 1" * 1" wafer cost = $15.
- CVD diamond rad hard, mono-crystal avoids noise issues of previous polycrystalline CVD diamond

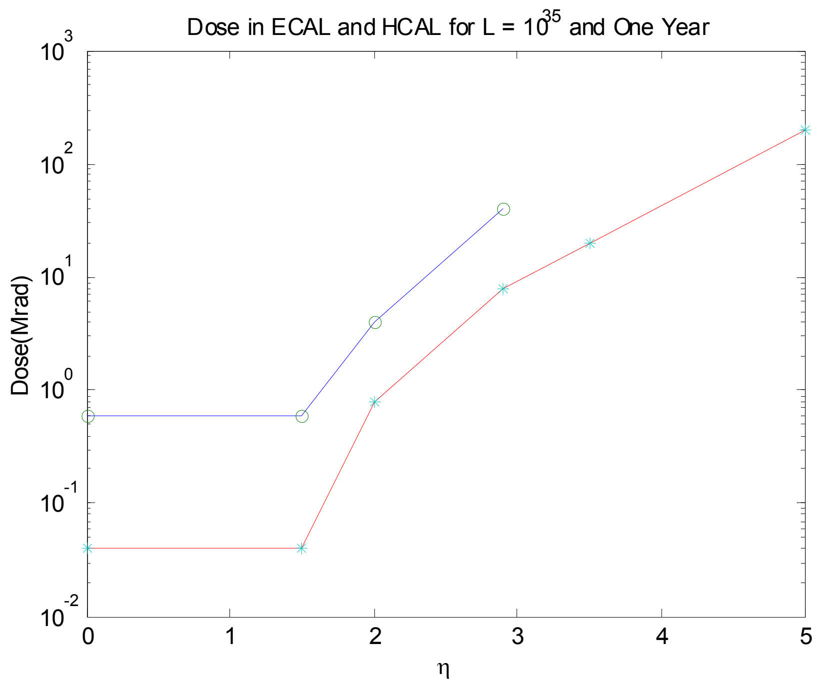
Why Work at FNAL?

- Construction and operation of SiTrk in hadron environment
  - We know what to do and what not to do
- Real life experience in using SiTrk data
  - Understanding si clusters and resolution
- CMS construction in the US = TOB + Forward pixels
  - Experience with CMS detector structure and DAQ
- Extensive facilities for R&D, fabrication, testing

Why now?

- CMS SiTrk detectors design time line
  - RD2 report – 1994
  - CMS technical proposal - 1994
  - RD20 report - 1995
  - RD48 report – 1997
  - Start construction phase 2003
  - Start data taking 2007 = 1994+13years
- SuperLHC start data taking 2014
  - RD?? report 2014-13=2001
- Should have started two years ago!

HCAL and ECAL Dose



Barrel doses are not a problem. For the endcaps a technology change may be needed for 2 < |y| < 3 for the CMS HCAL. Switch to quartz fiber as in HF?

CMS ECAL

Crystals

Barrel: OK

Endcap : 3krad/hr at η=2.6

Further studies at high dose rates, long term irradiation

Photosensors

Barrel: APDs – higher leakage current a higher noise ~100 MeV/ch

Endcaps: VPTs – **R&D**: on new devices may be needed

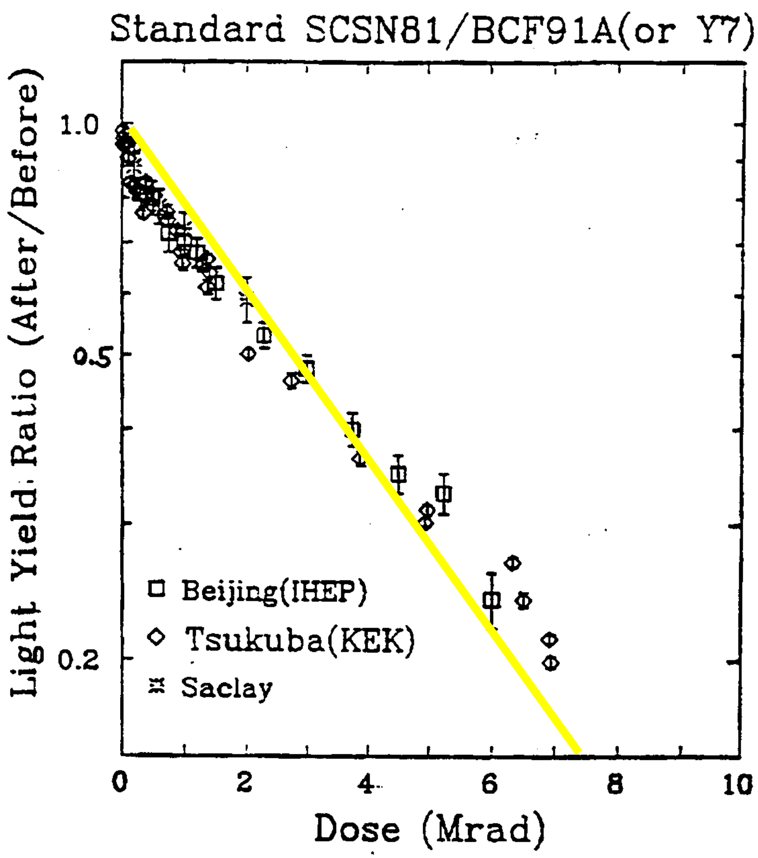
Electronics

Barrel: OK

Endcap: **R&D:** More rad-hard electronics at |h|~3?

Activation: in endcaps reach several mSv/h – access will be difficult

Scintillator - Dose/Damage



Scintillator under irradiation forms Color centers which reduce the Collected light output (transmission loss).

LY ~ exp[-D/Do], Do ~ 4 Mrad

This technology will not survive gracefully at |y| ~ 3. Perhaps use the technology that works at LHC up to |η|~ 5, quartz fibers.

Group including Notre Dame working on new rad-hard scintillators.

HCAL

- HCAL will function in the barrel region.
- In the 3<|y|<5 region, a reduction to y < 4.2 keeps the dose constant. Or replace quartz fibers with high pressure gas? Better tower granularity might be needed due to pileup and "fake" jets.
- At |y| ~ 3 the scintillator needs development – improved scintillator or go to quartz fibers (volume degraded is quite small).

Meson Test Beam Facility

Meson Lab Experimental Area

Meson Test Beam Facility http://www-ppd.fnal.gov/mtbf-w
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Meson Test Beam Facility

Mtest – the western-most beamline in the Meson building.

- **User facilities: 6 areas – MT6A1 - 2 & MT6B1 – 4. Two locations are enclosed with A/C, etc. Gases, data and HV cables, trigger and DAQ are supported by the Lab.**
- **Type of beam: Secondaries from Main Injector 120 GeV protons on an Al target at 0^{o}.**
- **Modes of operation:**
  "Proton" ~1 MHz of 120 GeV protons.
  "Pion" ~50 kHz of 5 – 80 GeV secondaries (rate depends on E).
  e's ~ 10-20%, μ's ~ 5%, π's ~ 80%; neg. polarity poss.
- **Beam size: 1 cm^2**
- **Instrumentation: 80' & 50' Cerenkov counters; 0.5 & 1.0 mm beam PWCs; etc.**

Test Beam Facility

Booster Radiation Damage Facility

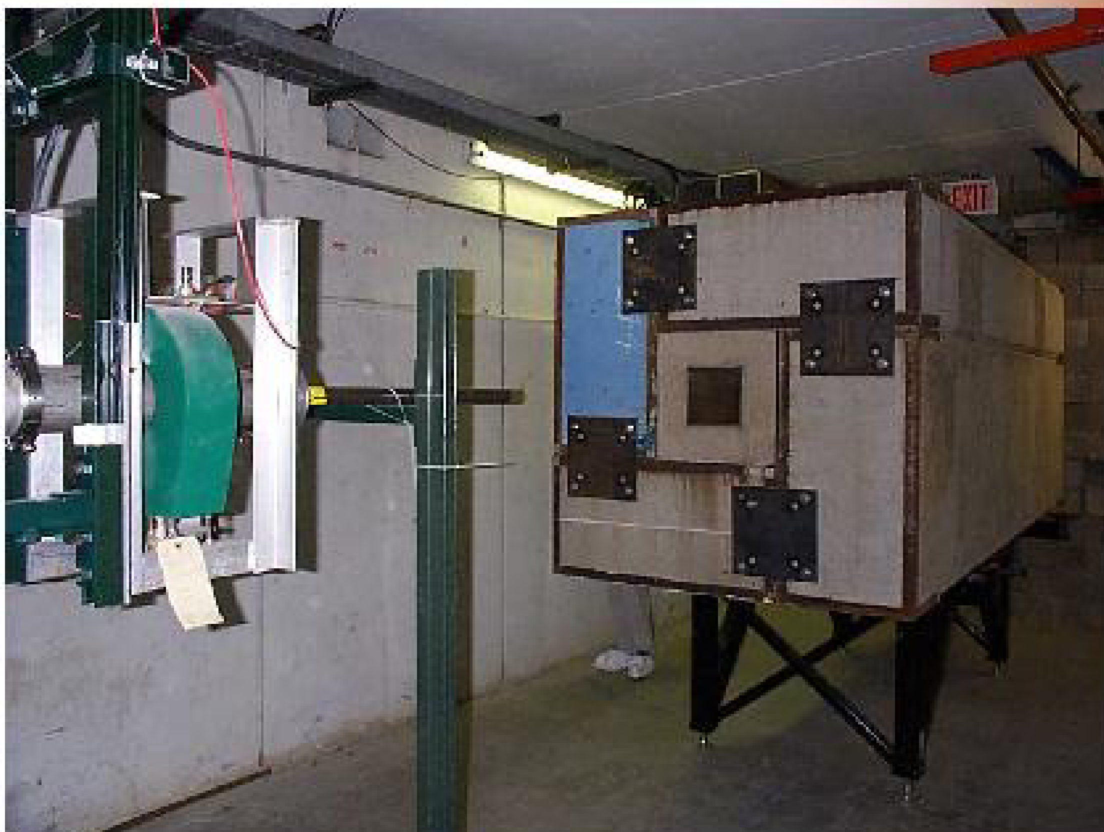
- Energy = 8 GeV.
- 3 E11- 4.5 E12 protons/1.6 μs pulse, monitored with a toroid.
- Rep rate: 0.2 – 3 s depending on HEP demands.
- Circular beam size: FWHM = 1.2 cm measured with an MWPC.
- Temperature controlled box (e.g. 5^{o}C).
- Motorized table.

- In a D0 test of Run 2 Si micro-strips a total dose of 2.1 Mrads (~7 E13 protons/cm2) was delivered to measure:
  1. depletion voltage
  2. Leakage current
  3. <noise>
  4. # of noisy channels, etc.

Booster Rad Dam Facility

Proton Source Department

New 8 GeV Radiation Damage Facility



Beams Division Seminar
11/2/99

Facilities at Fermilab

- Scintillator Development Facility at Lab 6
- SiDET
- Electrical Engineering Labs and Expertise
- Test Beam, Radiation Damage Facilities

Summary

- **The LHC Physics reach will be substantially increased by higher luminosity.**
- **To realize that improvement, the LHC detectors must preserve performance.**
- **The trackers must be rebuilt – with new technology at r < 20 cm.**
- **The calorimeters, triggers and DAQ will need development.**
- **The upgrades are likely to take ~ (6-10) years. Accelerator is ready ~ (2012, 2014). The time to start is now. New collaborators are Welcomed!**