Summary of the Phase 1 Tracker Upgrade Session

Simon Kwan
Fermilab

Phase 1 Pixel Upgrade Plan

- Plan formed in 2008
- Assumption was ready in 2013
- BPIX: 3 layers to 4 layers
- FPIX: 2x2 disks to 2x3 disks
- Reduce Material
- CO2 cooling & light-weight mechanics
- Move material budget out of the tracking region
- Increase number of pixel hits from 3 to 4 up to eta of 2.5
- Pixel track and vertexing significantly improved and more robust

Constraints and modifications

- Use existing cables, fibers, cooling pipes
- Same FECs, TTC & ROC programming
- Try to use same power supply system
  - Turn-out to be problematic even with modified CAEN LV power supply modules
- DC-DC conversion will be used
- ROC same technology, add more buffers, 8 bit on-chip ADC, 160 MHz digital readout
- Serialized binary readout at 320 MHz to modified pixel FED
- New AOH to transmit digitally at 320 MHz
- Baseline is to sue same n-on-n sensor technology

Phase 1 Tracker Upgrade Session

[8] **Introduction** — slides
by Simon KWAN (Fermilab)
(10:00 - 10:05)

[9] **Beam pipe diameter for future pixel systems** — slides
by Dr. Roland HORISBERGER (PSI)
(10:05 - 10:15)

[10] **Radiation hardness of present pixel modules** — slides
by Tilman ROHE (Nuclear and Particle Physics Department)
(10:15 - 10:35)

[11] **Modifications for an improved pixel ROC with digital readout** — slides
by Dr. Hans-Christian KAESTLI (PSI)
(10:35 - 10:55)

[12] **Mechanics & Supplytube for a CO2 cooled 4 layer barrel pixel system** — slides
by Silvan Bjoern STREULI (Institut fuer Teilchenphysik-Eidgenossische Tech. Hochschule Zue)
(10:55 - 11:15)

[13] **Status of CO2 Cooling**
by Hans POSTEMA (CERN)
(11:15 - 11:35)

[14] **DC-DC Conversion for the Pixel System at Phase-1** — slides
by Ruediger JUSSEN (I. Physikalisches Institut (B)-Rheinisch-Westfaelische Tech. Hoc)
(11:35 - 11:55)

[15] **PIRE R&D activities for Phase 1 Pixel Upgrade** — slides
by Aaron DOMINGUEZ (University of Nebraska)
(11:55 - 12:15)

[16] **Results from the micro-twisted pair links** — slides
by sandra OLIVEROS (CMS)
(12:15 - 12:25)

lunch break
(12:25 - 13:30)

[36] **Blade & Half Disk Design for FPIX** — slides
by CM LEI (FermiLab)
(13:30 - 13:50)

[38] **Design of a prototype CO2 cooling system at Fermilab** — slides
by Richard SCHMITT (Fermilab)
(13:50 - 14:05)

[34] **Readout Architecture for FPIX** — slides
by Mr. Sergey LOS (Fermilab)
(14:05 - 14:20)

[124] **Phase 1 Optohybrid Plan**
by Dr. Jan TROSKA (CERN PH/ESE)
(14:20 - 14:35)

[37] **FPIX pixel module assembly**
by Mr. Kirk ARNDT (Purdue)
(14:35 - 14:50)

[35] **Power Distribution Studies of Fermilab/Iowa/UMiss** — slides
by Lalith PERERA (Physics and Astronomy Department-University of Iowa-Unknown)
(14:50 - 15:05)

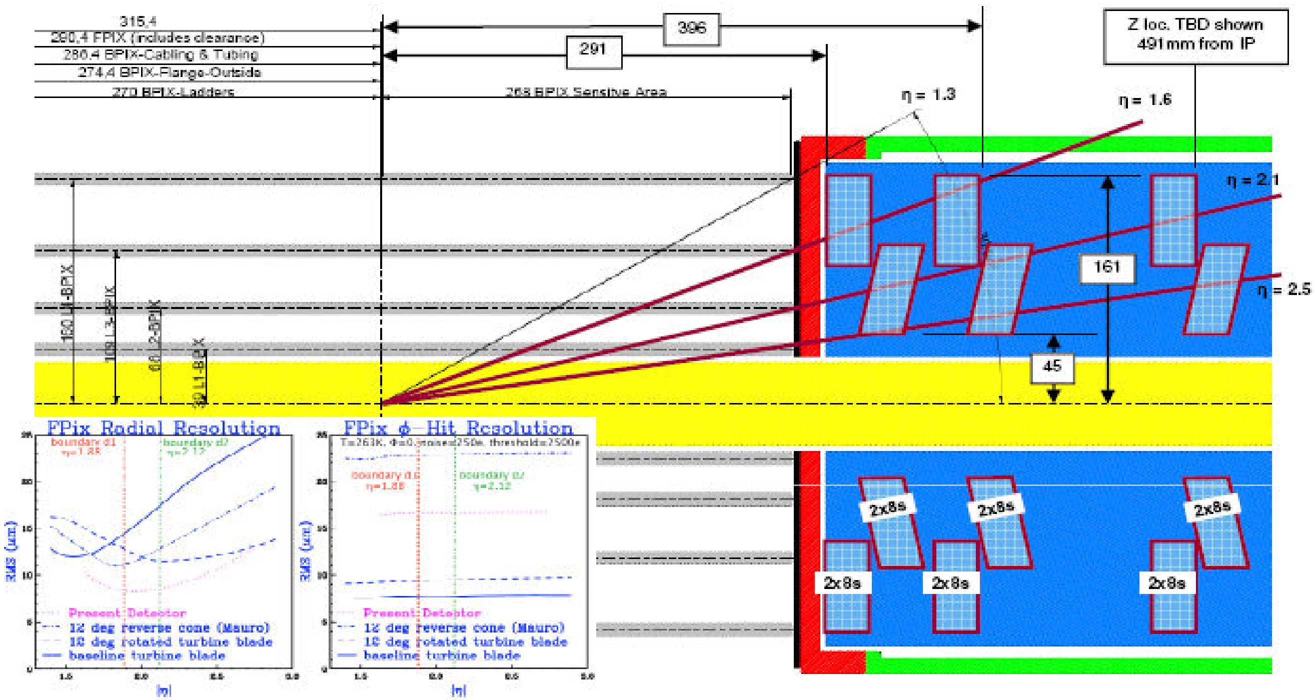
[85] **Phase 1 data rates for FPIX**
by Karl ECKLUND (Rice University)
(15:05 - 15:25)

[39] **Simulation studies for Phase 1 Pixel upgrade** — slides
by Pratima JINDAL (Purdue University Calumet)
(15:25 - 15:45)

Current Pixel Detector

- Understanding the limits of the current pixel detector
- Irradiation studies of single-chip pixel detectors at PSI
- Seems that at 2.8E15, one could get a signal of >5k electrons at a bias of 800V or higher
- For ROC,stay fully operational up to 5E15
- Issues: Sensor
  - Efficiency
  - Charge distribution -> resolution
  - Current HV power supply and cable limit to 600V
- ROC
  - Irradiation tests done without bias
- Detector assembly
  - Small signal size and in-time threshold
- Test Beam plan

BPIX/FPIX Envelope



Based on Morris Swartz's study, it's possible to optimize the layout to obtain excellent resolution in both the azimuthal and radial directions throughout the FPix acceptance angle since we have separate inner and outer blade assemblies.

Inverted cone array combined with the 20 deg Rotated Vanes for the inner blade assembly is thus decided.

Mechanics

- Good progress at PSI and Fermilab
- Bpix:
  - Prototype supply tube being fabricated and will be available for testing next spring
  - Installation clearance for new supply tube envelope verified in CAD
  - Installation tests with proto supply tube and dummy 4 layer BPIX in installation mockup planned ~ march 2010
- Fpix:
  - Mechanical design of half-disk and support completed
  - Prototype TPG substrate, ring support structure with SS cooling tube embedded in hand
  - FEA modeling in progress

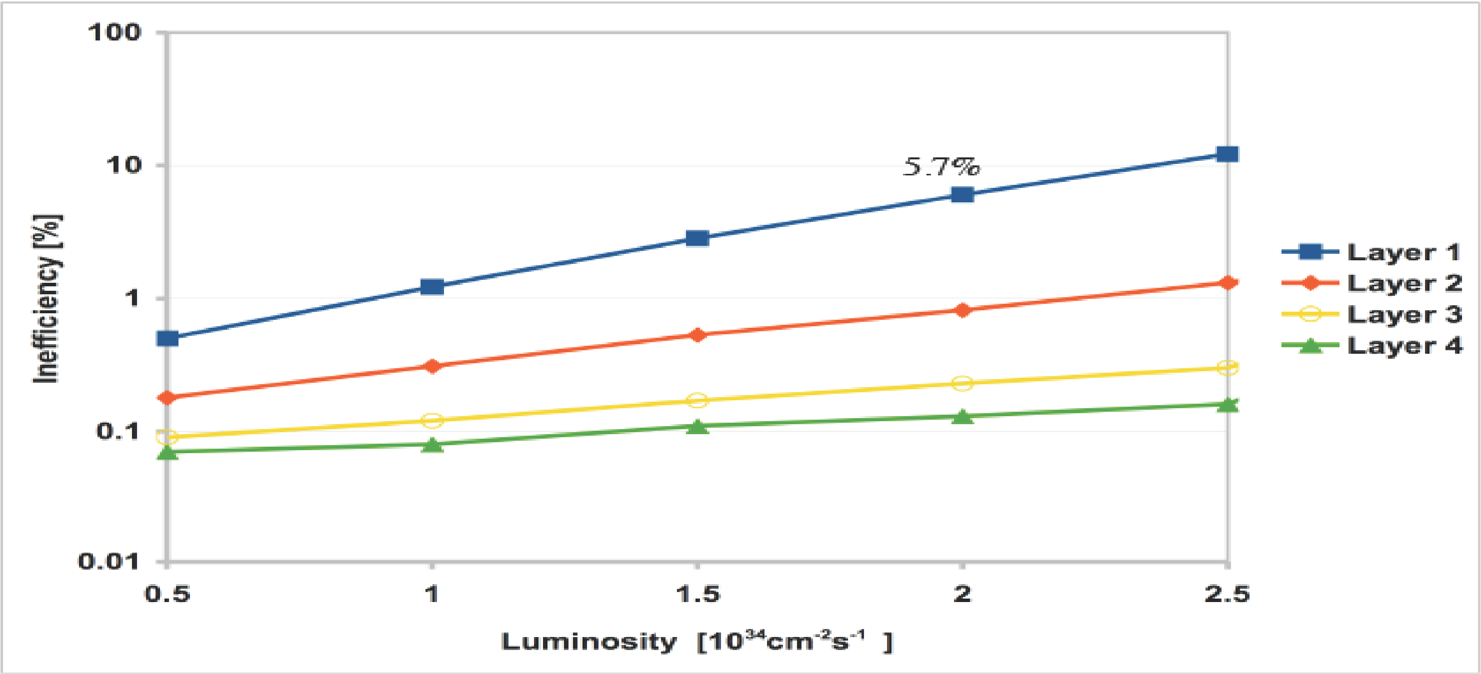
CO2 Cooling

- A lot of effort in Europe and US
- Simple flow system at CERN and Lyon
  - Measurements done to prototype Bpix cooling tube with heat load and compared with model calculations
- Joint ATLAS/CMS prototype system based on LHCb design now being built
  - Design approved and parts identified
  - Parts being procured
- US: Fermilab will produce a prototype CO2 cooling plant that can be expanded to full pixel system
  - Reviewed last week
  - Proceed with procurement and expect to be ready for commissioning early Summer 2010
  - Will ask CERN to do the first flow test of the prototype SS tube

Readout Chip for Phase I

- Based on present readout chip
- Limitations of present ROC at Phase1:
  1. Buffers sizes for L1 latency (dominating)
     → **Increase number of buffers**
  2. Readout related dead-time at higher data volumes
     → **Additional readout buffer stage**
  3. Higher module count / same number of fibres
     → **Digital readout**
     - On chip ADC
     - New fast digital readout links
     - PLL to provide higher frequencies
     - Modification to control logic
- Since we will be in competitive physics situation an implementation with **minimal impact on overall system** is mandatory (no big learning curve)
  - Changes in present 0.25μm ROC limited to small regions in interface block + buffer enlargement (trivial)
  - No change in down link chain
- All new critical functional blocks for ROC modification produced and testet
- Very good results. Behaviour as expected, except ADC
  - Too slow (factor 3 slower than in simulations)
  - Problem probably understood, need further checks
  - Solution basically in hand
- Next step: irradiation of test structures

Inefficiency vs luminosity



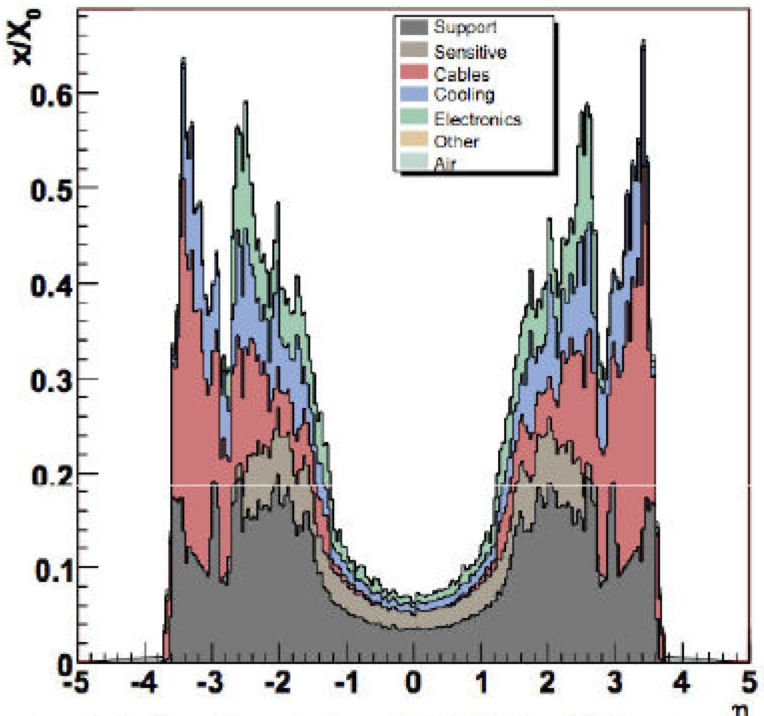
→ Inefficiency depends exponentially on luminosity

Simulation has no safety factor
May be optimistic due to quality of simulation, typical events at 14 TeV; Simulation should be repeated after we have some real data at 14 TeV
Limit of the technology and architecture

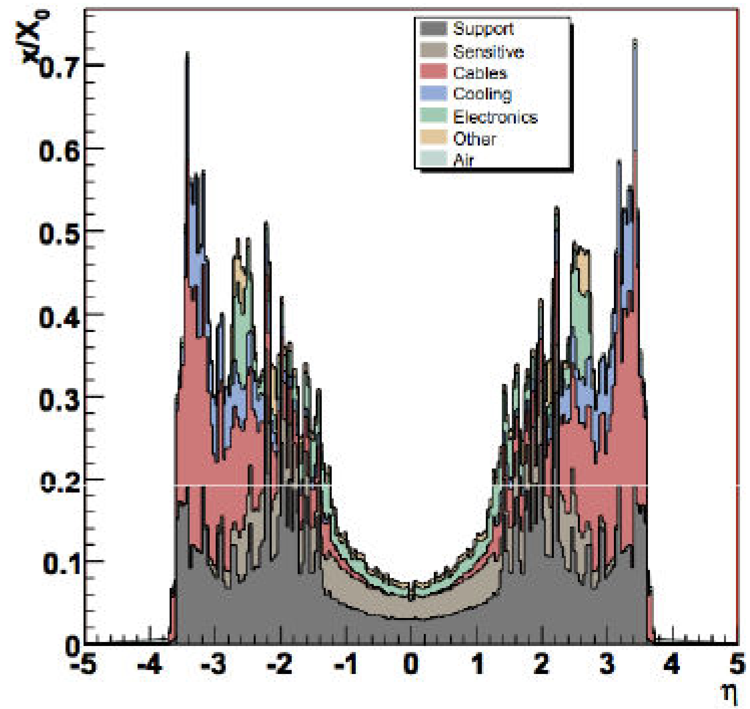
DC-DC conversion

- CERN group is developing radiation-hard custom ASIC for DC-DC conversion
- Two different rad-hard technologies have been identified and 3 different chips have been produced
- AMIS2 chip being evaluated at Aachen and will also be tested on pixel detectors at Fermilab
- Also need modification to the existing CAEN power supply module
- Problematic – very expensive and won't need our needs; needs a new design

Material Budget



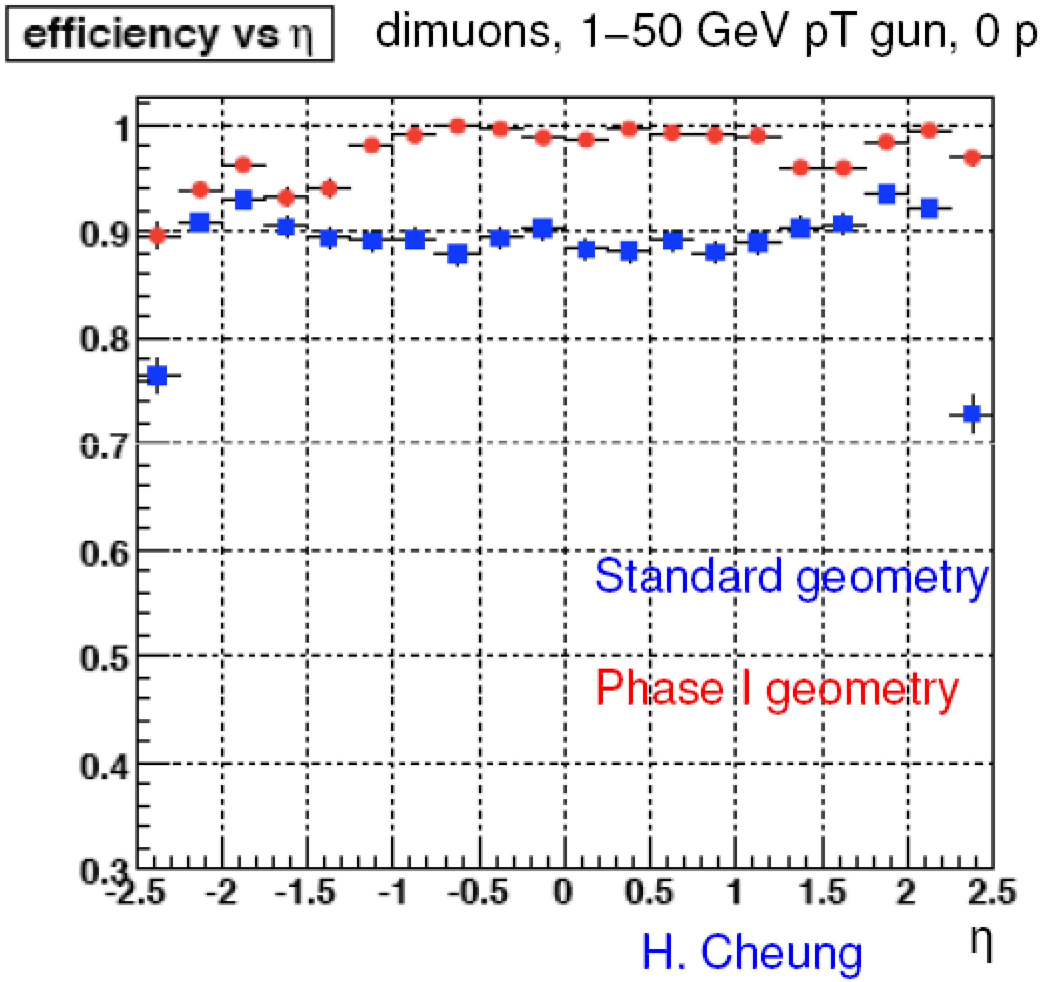
Material Budget for Std Pixel System



Material Budget for Phase I Pixel System

- The material changes for BPIX implemented by
  - rescaling the corresponding material densities to reproduce the correct new weights
  - C_6F_{14} → CO_2 with rescaled density of 0.20 g/cm^3
  - Al pipes → Steel_Upgrade with rescaled density of 0.49 g/cm^3

Efficiency



- We are trying to understand if we can have higher efficiency at the same or better fake rate using 4 barrel layers and/or 3 disks
- Compare the efficiencies using triplet seeds (3-out-of-3) for standard CMS geometry and triplet seeds (3-out-of-4) for Phase I geometry

- We see a lower efficiency on the negative side
- Issues with tracking because of local coordinate vs global coordinate systems in the new geometry
- Working on resolving this

Observation and comments

- Plan was developed when we thought we had to have the detector ready in 2013
- With the change in LHC schedule, we have now more time to pursue new options
- Need to develop and establish a clear set of requirements: detector performance for the duration of Phase 1 (acceptable data loss, vertex resolution, efficiency etc)
- Need more studies on the performance of the Phase 1 detector – physics reach
- We should come to some decision on an updated schedule for Phase 1and the timeline of the TDR

Revised strategy for the Phase 1 Pixel Upgrade

The strategy of the Phase I pixel upgrade project discussed end of last year (2008) was heavily driven by the notion that we had a deadline of ~2013÷2014 to have a detector ready for installation, which appeared extremely tight. The incident of last year led to a delay of one year and the problems encountered have also introduced uncertainty in the luminosity evolution. It is clear now that even in the most optimistic scenario for the evolution of the LHC luminosity, the present pixel detector will not suffer significant radiation damage until much later, and the motivations for an early pixel upgrade, although valid, may not be considered sufficiently compelling by some Funding Agencies.

Given the uncertainties, flexibility is the key factor to keep in mind when planning the upgrade. If the integrated luminosity rises slowly such that the present detector might need to be replaced by 2015-16 we can take the opportunity and start developing more radiation tolerant sensors (and possibly new electronics) for the inner layers to make the upgraded detector more radiation resistant than previous one. This could allow the upgraded detector to survive until the end of Phase I. If these developments would require longer time, the full upgraded detector will be initially populated with the current planned technologies and the first two layers/rings will be upgraded later on when the development will be mature. The new mechanics and services possibly should be designed to allow the insertion of a layer0/ring 0, taking advantage of a possible future scenario for a reduction of the radius of the beam pipe.

Possible dates for Phase I TDR or addendum TDR need to be re-defined (early 2011 could be a possible target to be discussed).

With this strategy we should be able to provide to CMS an upgraded pixel detector that may integrate opportunities (for example beam pipe size reduction) as they might become available, including developments of technologies (if they become mature in time) for a more radiation resistant and better performance detector.