

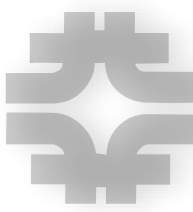
(CMS Operations and) CMS Upgrades

Resource Planning Meeting

L.A.T.Bauerdick



SLHC Upgrade Baseline



- ◆ LHC upgrade baseline planning foresees two phases
 - ★ phase 1 to provide reliable operations at $2 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ with replacement of interaction region insertion quadrupoles and a new injection Linac
 - ◆ baseline schedule: to be completed in 2014, long shutdown (6-9 months) in 2013
 - ★ phase 2 to reach $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ around 2020)
 - ◆ decision on phase 2 to be taken around 2012,
 - ◆ with major shutdown (12-18 months) that would allow experiments to make major detector upgrades



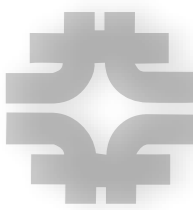
SLHC Upgrade: Likely delay



- ◆ Sep 2008 LHC incident led to a schedule delay of more than a year
 - ★ makes prediction of luminosity evolution ever more uncertain
 - ★ need for replacing detectors to handle instantaneous and integrated luminosity further delayed, as LHC schedule foresees a run at low luminosity in 2009/10 and a likely long shutdown in 2011
 - ★ it's unlikely we reach a few hundred fb^{-1} before 2015/16, reducing the urgency to upgrade services due to radiation damage
 - ★ however, instantaneous lumi to reach $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ by 2013/14, so there is specific justification for upgrades to cope with instantaneous lumi, and also upgrades related to robustness etc to make the best of lower lumi
 - ★ expect that construction for phase 1 will start later and stretch out longer
 - ★ phase 2 R&D keep going at low level until there is better understanding
- ◆ currently the official plan is still the “baseline plan”, although it is obviously not to happen
 - ★ correspondingly the planned CD-0 review of the US upgrade construction project planned for this November has been delayed
 - ★ we do not expect to get US construction funding for phase1 in FY10



Upgrade Projects (Phase 1) with Planned US Contributions



★ HCAL

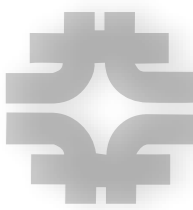
- ◆ implementation of longitudinal segmentation
- ◆ new sensor, SiPM
- ◆ new trigger/readout receiver electronics → regional calorimeter trigger
 - ◆ addressing concern of instantaneous lumi, integrated lumi, improve trigger

★ Pixel system

- ◆ replacement of current system with 4 barrel layers and 3 forward disks
 - ◆ currently 3 layers, and 2 disks
- ◆ we know we'll have to do it but aren't sure when
 - ◆ perhaps get it ready for a "optimistic" date and install whenever there is opportunity
- ◆ employ limited info from Pixel detector in Level-1 trigger
 - ◆ driven by radiation damage (integrated lumi) and instantaneous lumi



Upgrade Projects (Phase 1) with Planned US Contributions, cont'd



- ★ Trigger
 - ◆ rebuild regional calorimeter trigger (μ TCA) , and CSC trigger track-finder
 - ◆ driven by instantaneous lumi and overall efficiency
- ★ EMU
 - ◆ addition of chambers in the 4th endcap muon layer
 - ◆ upgrade layer-1 electronics to include into trigger
 - ◆ muon trigger primitive electronics
 - ◆ addressing concern of instantaneous lumi
- ★ DAQ
 - ◆ increase the bandwidth by a factor of 2-5 necessary to cope with increase peak luminosity
- ★ expect SLHC upgrade to be similar in scale.cost to the original detector construction project
 - ◆ perhaps 25% of this will be devoted to phase 1 upgrade
- ◆ significant R&D is already underway

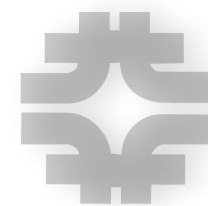
CMS Upgrade Plan

Reduced performance

Severe degradation

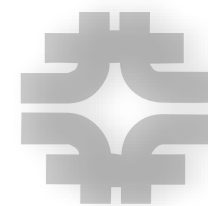
Component	10^{34}	3×10^{34}	10^{35} or prolonged Phase 1
TRACKER Pixel	OK	Rad/Occ: Replace/Add layers/disks	Rad/Occ: Full Replacement
TRACKER Strip	OK	OK	Rad/Occ: Full Replacement
ECAL Barrel	OK	OK	OK
ECAL Endcap	OK	OK	Rad high η : replace
HCAL Barrel	OK	Performance: Upgrade readout X4	No further action
HCAL Endcap	OK	Rad: Upgrade readout X4	Rad high η : new scintillators
HCAL Forward	OK	Rad: Upgrade readout X2	Rad/Occ: replace
HCAL Outer	HPD upgrade	No further action	No further action
MUON Drift Tube Barrel	OK	Change minicrates	Occ: upgrade electronics
MUON Cathode Strip chambers Endcap	OK	Occ: Add planes	Occ: upgrade electronics
MUON Resistive chambers Endcap	OK	Occ: Add planes	Occ: upgrade electronics
TRIGGER	OK	Enhancements	Occ: tracking in L1 trigger

Phase 1 cost

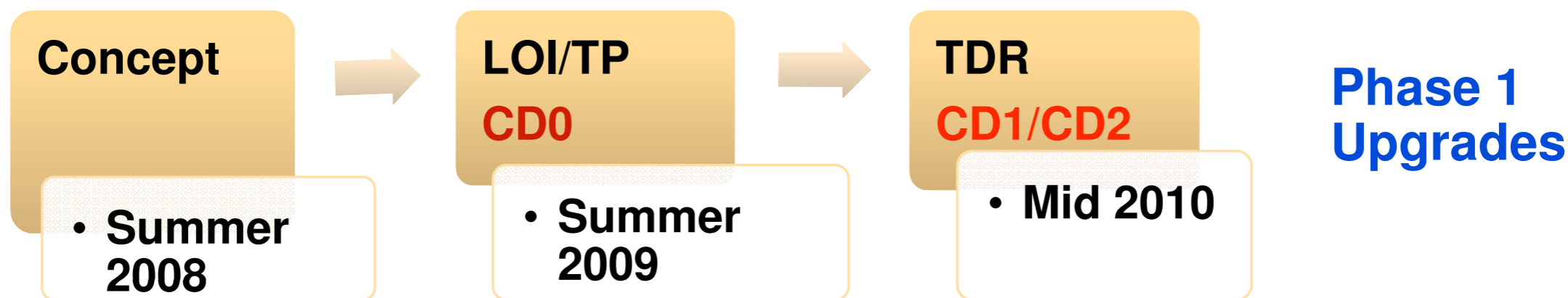


◆ Phase 1 cost presented to DOE and NSF in September 2008

Sub-Detector	Estimated Cost in FY08 \$	Estimated US Share in FY08 \$
Pixel System	30.2M	7.0-9.0M
CSC Muon System	8.6M	6.0-7.0M
RPC Muon System(*)	16.1M	0.0M
DT mini crates (*)	1.7M	0.0M
HCAL	10.2M	5.0-7.0M
ECAL	2.2M	1.0M
Trigger	8.5M	3.5-5.0M
DAQ	3.4M	0.0M
Tracker TDR for Phase 2	6.0M	0.0M
Infrastructure	10.0M	0.0M
Project Management	2.0M	1.0M
TOTAL	98.9M	23.5-30.0M



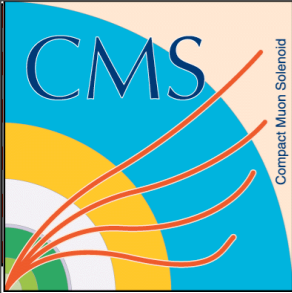
- ★ The R&D for Phase 1 plan moves rapidly from individual components, which require radiation testing (FY09-FY09) to more highly integrated structures (FY09-FY10), which will form the basis of a TDR in 2010



- ★ Strong simulation effort ongoing to formulate the Phase 2 plan. Extremely challenging environment will require innovative solutions

- ★ new tracker in extreme radiation and tracker info at trigger Level-1



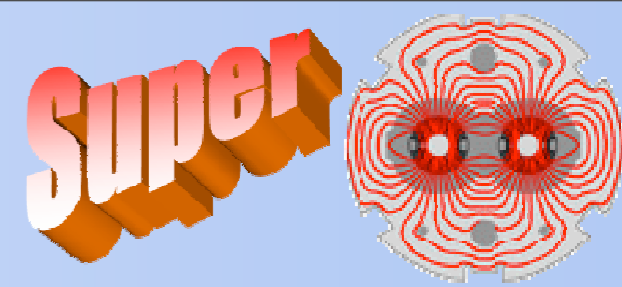


US R&D proposal submitted to CMS



1. Research and Development for CMS tracker in SLHC era Lenny Spiegel (Fermilab), Regina Demina, Yuri Gotra, Sergey Korjenevski (University of Rochester) + others European groups September 2006 **Approved 06.01**
2. SLHC Calorimeter Trigger R&D Program University of Wisconsin October 2007 **Approved 07.04**
3. CSC Level-1 Track-Finder Trigger upgrade Florida, Rice, UCLA October 2007 **Approved 07.05**
4. Study of suitability of magnetic Czochralski silicon for the SLHC CMS strip tracker Panja Luukka, Jaakko Härkönen, Regina Demina, Leonard Spiegel October 2007 **Approved 07.06**
5. R&D for Possible Replacement of Inner Pixel Layers With Aims for an SLHC Upgrade Alice Bean, Timothy Bolton, Aaron Dominguez, Wolfram Erdmann, Cecilia Gerber, Roland Horisberger, Angel López October 2007 **Approved 07.07**
6. CSC Endcap Muon Upgrades Contact Person: Jay Hauser October 2007 **Approved 07.10**
7. Reference Link Project For High Speed Optical Data Link R&Ds SMU, Minnesota and OSU October 2007 Approval Pending **07.11**
8. The Versatile Link Common Project Francois Vasey and Jan Troska, Physics Department, CERN, Geneva, Switzerland Christian Olivetto and Jean-Marie Brom, Institut Pluridisciplinaire Hubert Curien, Strasbourg, France Cigdem Issever, Todd Huffman and Tony Weidberg, Department of Physics, Oxford University, United Kingdom Jingbo Ye, Department of Physics, southern Methodist University, Dallas TX, USA November 2007 **Approved 07.12**
9. 3D detectors for inner pixel layers Daniela Bortoletto/Simon Kwan December 2007 **Approved 07.13**
10. CMS HCAL Calorimeter Electronics Upgrade Drew Baden, University of Maryland December 2007 **Approved**
11. Proposal for US CMS Pixel Mechanics R&D at Purdue and Fermilab in FY08 Daniela Bortoletto, Simon Kwan, Petra Merkel, Ian Shipsey, J.C. Yun December 2007 **Approved 07.15**
12. R&D for Thin Single-Sided Sensors with HPK Contact Person: Marcello Mannelli January 2008 Approval Pending **08.01**
13. Power Distribution System Studies for the CMS Tracker Fermilab, Iowa, Mississippi (Contact Person: Simon Kwan) June 2008 **Approved 08.04**
14. US CMS detector upgrades for PHASE 1 of the LHC luminosity upgrade US CMS (Contact Persons: Daniela Bortoletto, Joel Butler) July 2008 **Approved 08.05**
15. Proposal for Cooling R&D for the Upgrade(s) of the CMS Tracker Antti Onnela, Hans Postema, Paola Tropea (CERN) July 2008 **Approved 08.06**
16. Proposal for a First Level Trigger based on Tracking Lyon, Bari, Florence, Pisa, Barcelona, Boston, Minnesota, Brown (Contact: Fabrizio Palla) November 2008 Approval Pending **08.07**

PHASE 1: Pixel Upgrade



- **Baseline: 3 layers (4 layer option) and 3 disks in each endcap**

1) Sensor: Baseline n⁺-on-n as in current detector. R&D proceeding for Phase 2 on n⁺-on-p, 3D, diamond. One of these options could be used in inner layer if ready. Note n⁺-on-p requires one sided processing and could bring significant cost reduction

2) Changes to ROC, Token Bit Manager chip & pixel Front End Driver card for new 160/320 MHz serial binary readout (needed for 4th layer)

- Core of the readout chip remains unchanged
- Double ROC buffer size to reduce deadtime (enough for Phase 1)
 - In 250 nm CMOS an extra 0.8 mm is needed for periphery
- Introduce 1 ADC for pulseheight to ROC for 160 MHz data transmission

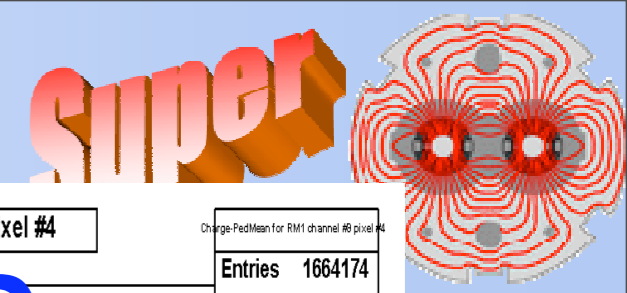
PSI with
PIRE
participation

3) Mechanical R&D

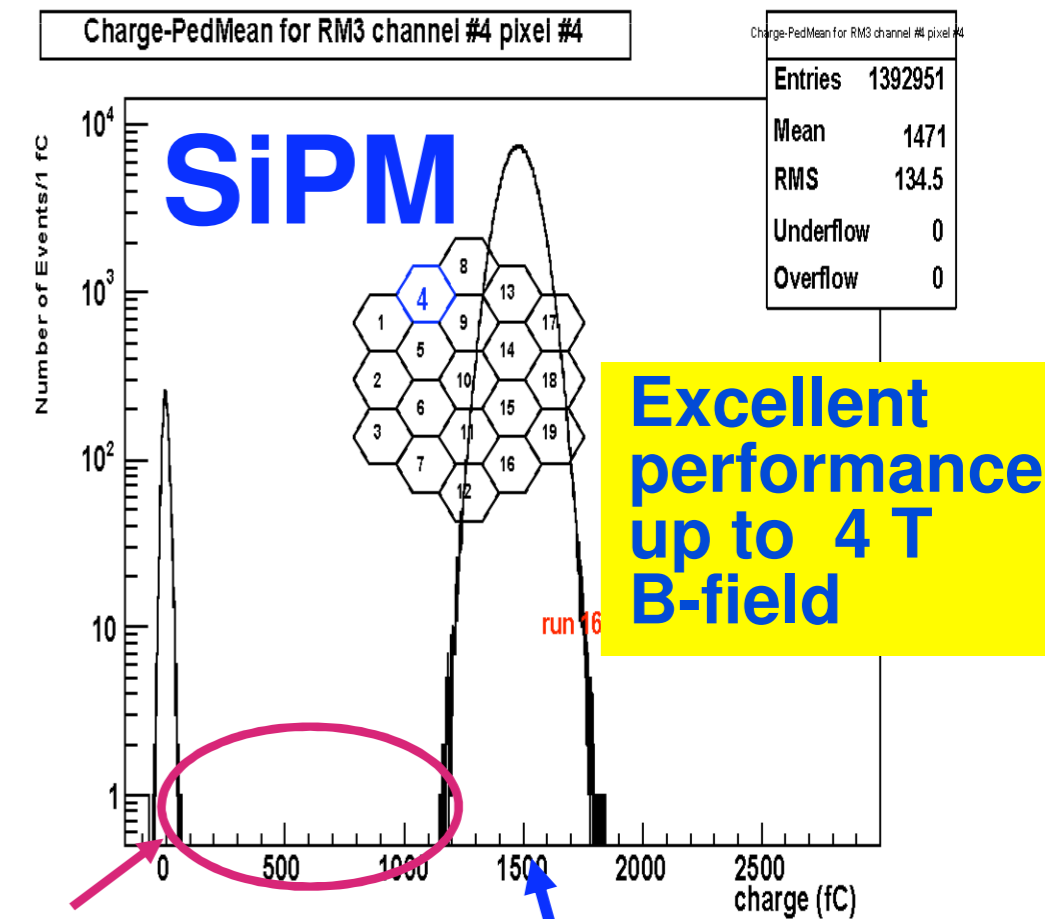
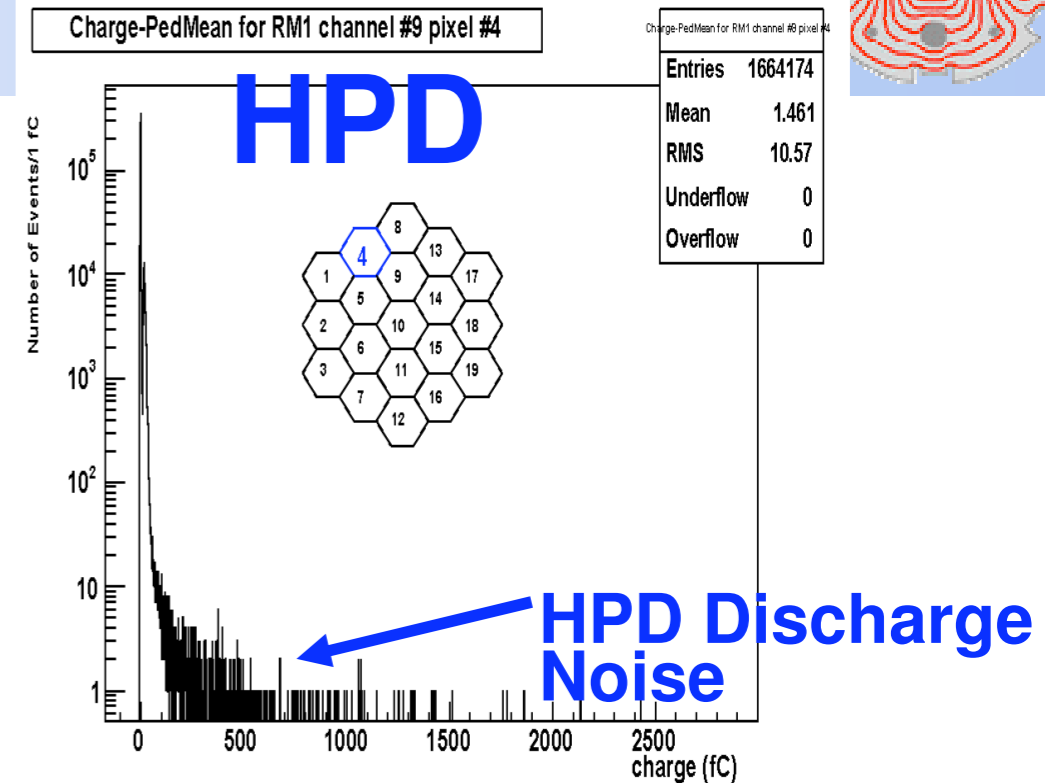
- Reduce # of module types and interfaces. One type of module (with 2x8= 16 ROCS) instead of 7 module types as in current FPIX detector.
- Integrate CO₂ cooling and lightweight support
- Improve cooling and cable routing, move control and optical hybrids out to higher η

⇒ **Reduce material budget by a factor of 3 (2) in barrel (endcap)**

Phase I HCAL Upgrade



- Major concept is replacement of Hybrid Photo Diodes (HPD) with Silicon Photo Multipliers (SiPM)
 - Work well in B field
 - Higher gain and Quantum Efficiency
 - Less noise (in MeV)
 - Can split signal to a TDC
 - Operates at ~50V (not 8KV)
 - Compact geometry allows new segmentation possibilities
 - Good radiation hardness
 - Changes in the front end will also lead to trigger improvements
 - Keep current fiber plant and services
 - Big cost and schedule savings but with technical challenges

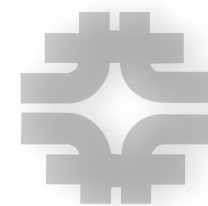


No tail in pedestal dist.

LED calibration pulse



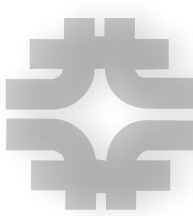
CMS Upgrade R&D



- ◆ while the planning for the upgrade makes progress, with major unknowns concerning the t0, the upgrade R&D continues and ramps up
 - ★ FY08: \$1,353k, FY09: \$2,500k, expect FY10: ~\$3,500k, FY11: ~ 4,150k
- ◆ all upgrade R&D currently is funded through the US CMS Operations Program
 - ★ so in the spreadsheet this effort shows up in the CMS Operations project
 - ★ mostly HCAL SiPM and Pixel mechanics/cooling/power R&D, simulations
 - ★ the FY10 US CMS budget, including the Upgrade R&D budget is still being reviewed and defined, I'm showing tentative figures
 - ★ at Fermilab the planned Upgrade R&D effort in FY10 will likely be about 8.6 FTE: 4.9 engineers, 3.5 technicians and 0.2 drafters
 - ★ most of this effort is in Pixels, some of it is in HCAL
 - ★ several senior scientists and a couple of RAs work on the Upgrade R&D part-time



CMS Operations, Non-Scientist Effort (USCMS Ops Program) in FY10

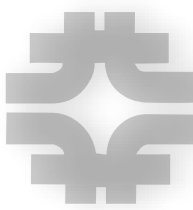


- ◆ for U.S. CMS the effort is split into S&C, M&O and CommonOps effort
- ★ for S&C we expect to have 33 FTE of computing professionals on-project
 - ◆ no engineering/technicians/drafters effort
- ★ for M&O and CO the expected total is 20.85 FTE

Personnel	Category	FTE to MO/RP	Funding Source	PPD/Other
Read	Administrative Supt	1	Com Ops	PPD
Farver	Administrative Supt	1	Com Ops	PPD
Gartung	APPLIC DEV & SYS ANALYST	0.5	Com Ops	CD
Lukhanin	COMPUTING SERV SPEC	1	Com Ops	PPD
Mommsen	COMPUTING SERVICES SPECIALI	1	DAQ	PPD
Shpakov	COMPUTING SERVICES SPECIALI	1	DAQ	PPD
Lusin	ENGINEER	1	Prog Office	PPD
Moccia	ENGINEER	0.5	.5 on MO .5 on PPD base	PPD
Soha	ENGINEERING PHYSICIST	1	Com Ops-ROC	PPD
Kramer	FUNCTIONAL ANALYST	1	Com Ops	PPD
Yoshikawa	PROJECT BUDGET SPECIALIST	0.5	Com Ops	PPD
Doody	PROJECT SUPPORT	1	Com Ops	CD
Sexton-Kennedy	APPLIC DEV & SYS ANALYST	1	Com Ops	CD
Badgett	COMPUTING SERV SPEC	0.25	ROC	PPD
Biery, Kurt	APPLIC DEV & SYS ANALYST	0.5	DAQ	CD



FY10 Effort continued



★ variable effort (people not “assigned” to CMS)

Personnel	Category	FTE to MO/RP	Funding Source	PPD/Other
Howell, Joseph	ENGINEER	0.5	Upgrade FPIX	PPD
Los, Sergey	ENGINEER	0.75	Upgrade FPIX	PPD
Prosser, Alan	ENGINEER	0.75	Upgrade FPIX	PPD
Rivera, Ryan	ENGINEER	0.75	Upgrade FPIX	CD
Turqueti, Marcos	ENGINEER	0.75	Upgrade FPIX	CD
Schmitt, Richard	ENGINEER	0.1	Upgrade FPIX	PPD
Lei, Chi Meng	ENGINEER	0.2	Upgrade FPIX	PPD
Holm, Scott	ENGINEER	0.1	HCAL	PPD
NN	ENGINEER	1	Upgrade FPIX & HCAL	PPD
	Drafter	0.2	Upgrade FPIX	PPD
	Technicians	3 0 + 0.5	Upgrade FPIX & HCAL	PPD

◆ we will in particular need engineering effort for the SiPM HO replacement (e.g. Los)

Clerical	2
Financial	0.5
Engineer	5.4 + 1
Computing	7.25
Eng Phy	1
Technicians	3 0 + 0.5
Drafter	0.2
	19.35 + 1.5

★ The upgrade scope is 4.9 engineers, 3.5 technicians and 0.2 drafters

◆ I added tentatively 1 Engineer and 0.5 Technician to FY09 effort, depending on budget review



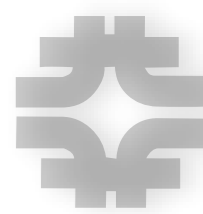
Estimated FY11 Effort



- ◆ FY10 effort will continue in FY11, at a slightly higher level
 - ★ no detailed R&D plans for the Fermilab group exists at this time, but expect we'll do more of the existing activities on HCAL and Pixels
 - ★ also the non-upgrade engineering effort will continue
 - ◆ e.g. the possible HF PMT replacement in 2011 (e.g. Los and Howell)
 - ◆ We may need engineering support for the hopefully last round of fixing the Tracker cooling system in 2010/2011.
- ◆ expect to have CD-0 and start of Upgrade Construction funding
 - ★ large uncertainties make detailed planning very hard:
 - ◆ expect total US program to be \$23 - \$30M, maybe with a first year of \$5M
 - ◆ with maybe \$3M personnel costs, of which possibly 50% will go to Fermilab
 - ◆ \$1.5M will buy us about 7 FTE at Fermilab
 - ★ we have a simple strawman model for the required manpower
 - ◆ based on three projects going (Pixel, SiStrip and Trigger upgrade projects)
 - ◆ given this funding scenario, Fermilab could start one of these in FY11
 - ◆ also zeroed out the Project Office assuming that year we can use the Ops office
 - ◆ given the uncertainties, I did not break out into quarters...



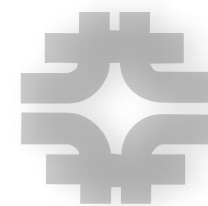
2007: Toy Model for CMS Upgrade at Fermilab



- ◆ Simple model, just to inform us about possible scale and scope
 - ★ the CMS upgrade project is not yet defined beyond very general considerations
 - ★ undetermined what parts the US and what Fermilab would take up
- ◆ Assumptions:
 - ★ design phase that would have Fermilab involved in electronics projects, ASIC design for Pixels, SiTracker, Trigger
 - ★ construction phase for three projects: part of the pixel and part of new tracking, part of new L1 trigger
 - ◆ highly qualified specialists and special facilities (e.g. ASICs)
 - ◆ installation teams that are willing to be located at CERN part time
 - ◆ integration of services, like cooling, cabling, high/low voltage etc
 - ◆ project office
 - ◆ did not include the physicist manpower and the software and computing efforts yet
 - ★ define manpower profile for these tasks, cost using escalated PPD rates
 - ★ assumption on M&S/procurements to be done through Fermilab



Estimated FY11 CMS Phase 1 Upgrade Needs



- ◆ for FY11 I filled this table into the CMS Phase 1 Upgrade table
- ★ and a slightly increased effort on Upgrade R&D into the CMS Operations table

	FY11
Application Scientist	0.2
ASIC Engineer	0.5
Controls Engineer	1
Designer - Electrical	0.7
Designer - Mechanical	0.2
Electrical Engineer	1
Electrical Technician	1
Electronics Engineer	0.7
Electronics Technician	1.1
Mechanical Engineer	0.2
Mechanical Technician	0.3
Tech Leader	0.2
	7.1



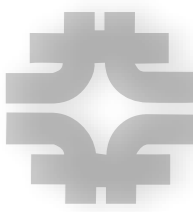
What went into the spreadsheet



- ◆ The spreadsheet did not allow me to do updates to CMS Operations, which contains the Upgrade R&D work, so I only updated the CMS Phase 1 Upgrade table
 - ★ the information is available in this talk and/or could be added on request
- ◆ for this exercise also zeroed-out the CMS Phase 2 Upgrade Construction as I have no information
- ◆ the input for CMS Phase 1 Upgrade is the estimated effort in the table for FY11, and propagating the previous estimates by 2 years



Summary



- ◆ There are significant uncertainties regarding both the scope and the time line of the CMS upgrade work at Fermilab
- ◆ The estimate done in 2007 is clearly not going to happen
- ◆ FY10 requires Upgrade R&D effort of ~5 FTE engineering and 3.5 FTE technician, 0.2 FTE drafter
 - ★ CMS Ops needs additional engineers
 - ★ Upgrade construction will not happen in FY10
- ◆ FY11 is largely unknown
 - ★ Upgrade R&D will continue, estimated to be ~constant
 - ★ Possibly we will require some 7 FTE for Phase 1 Upgrade Construction