Calorimetry Upgrade Task Force

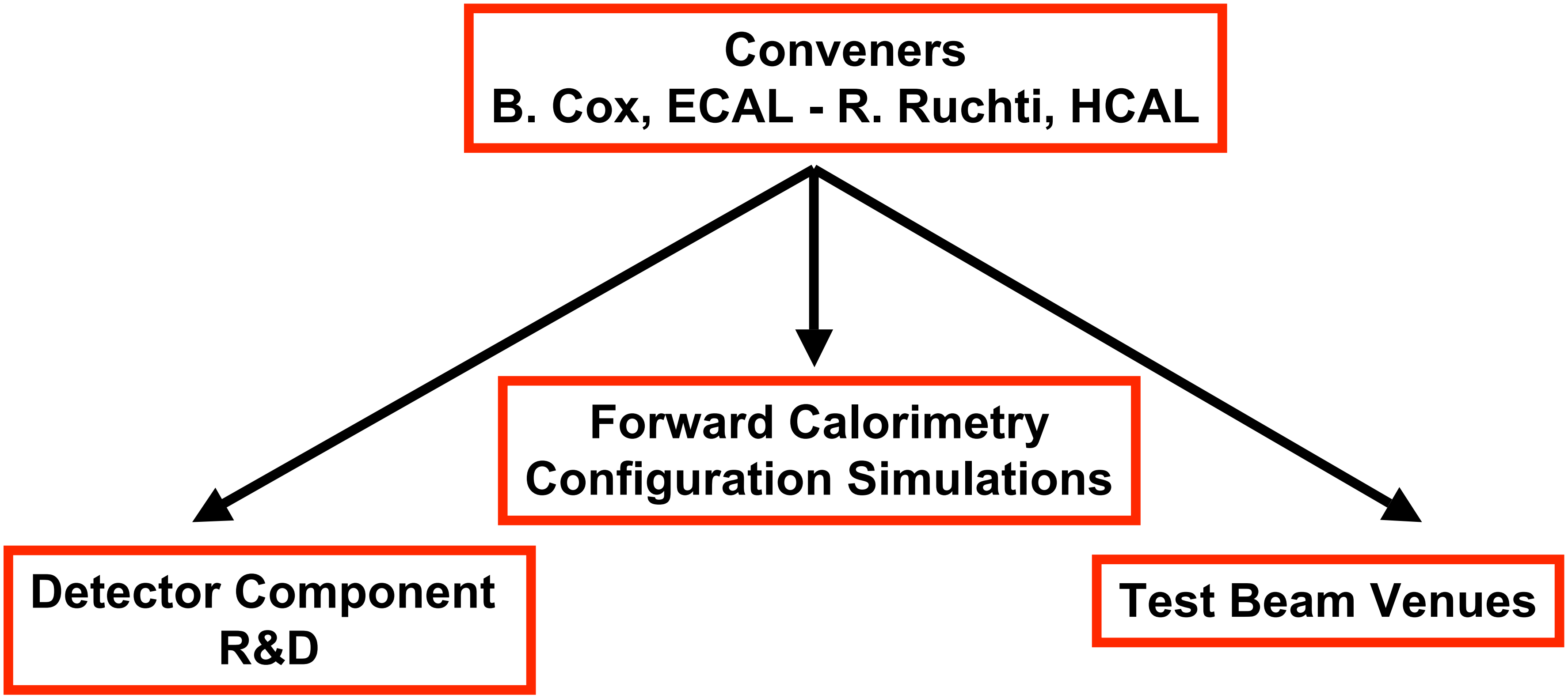
Brad Cox and Randy Ruchti
For ECAL, HCAL and other collaborators

Summary 30 October 2009

Meeting Format

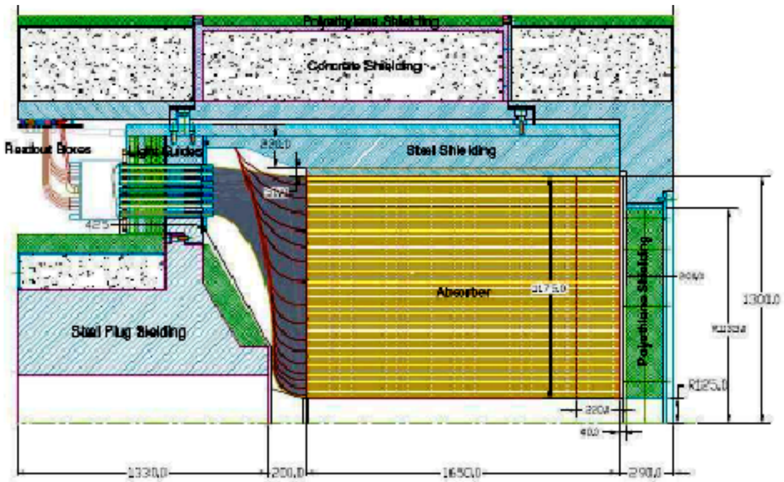
- Thursday, 29 Oct
  - Review of charge and planning
  - HCAL, ECAL overviews
  - Physics, simulation
  - Radiation effects
  - ECAL R&D
  - HCAL R&D
  - Test beams and irradiation facilities
  - R&D funding – prospects
- Friday, 30 Oct
  - General discussion and planning

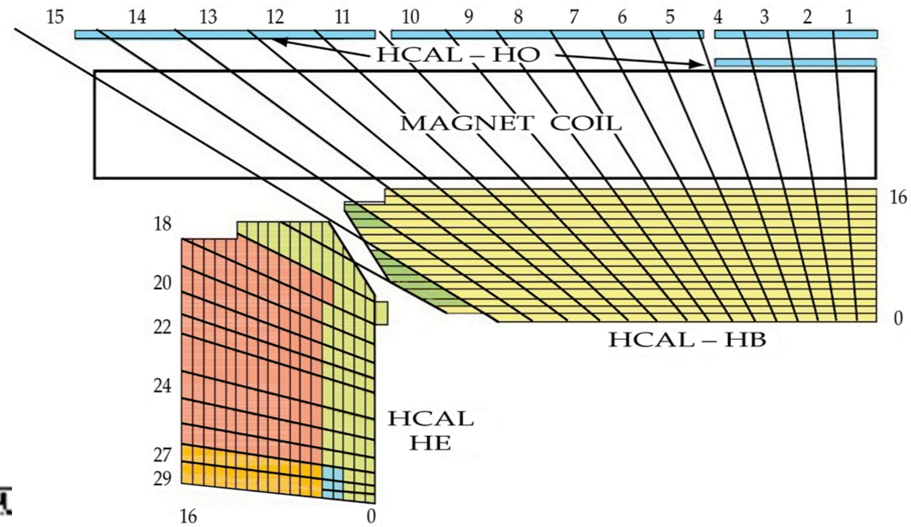
General Idea for the
Joint ECAL-HCALTask Force Organization

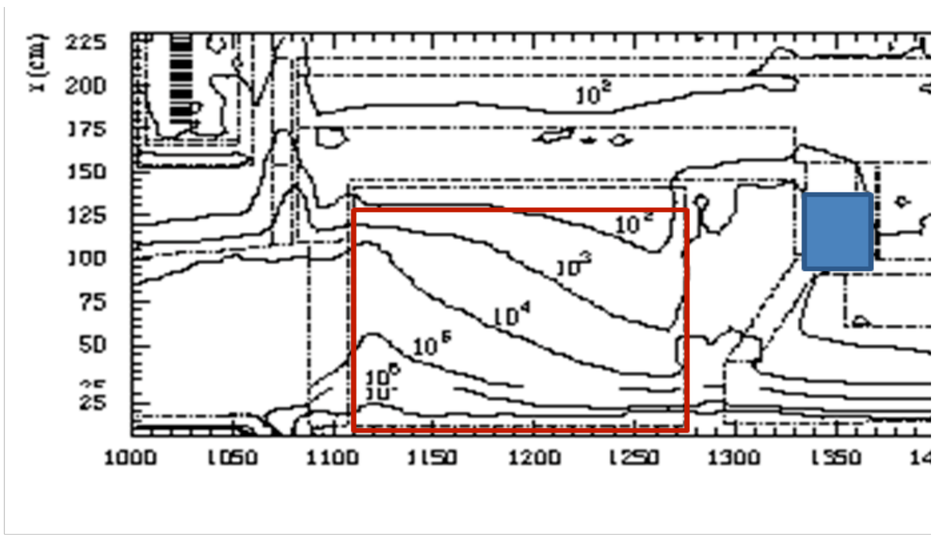


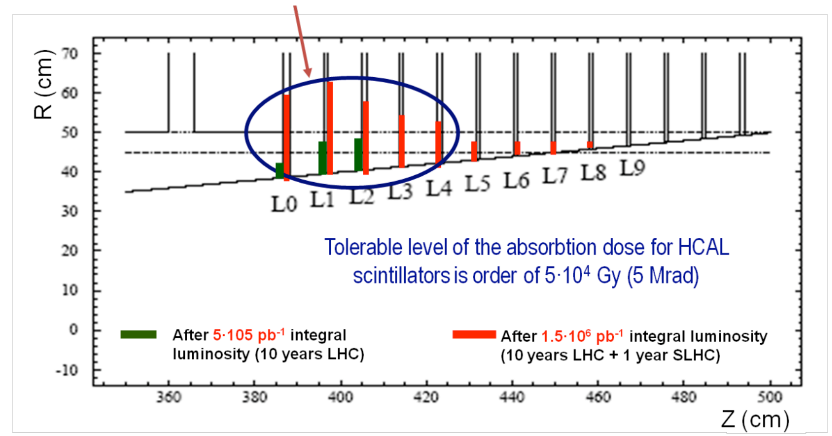
We will need dedicated people in all three boxes

From HCAL…Orientation (Ruchti)



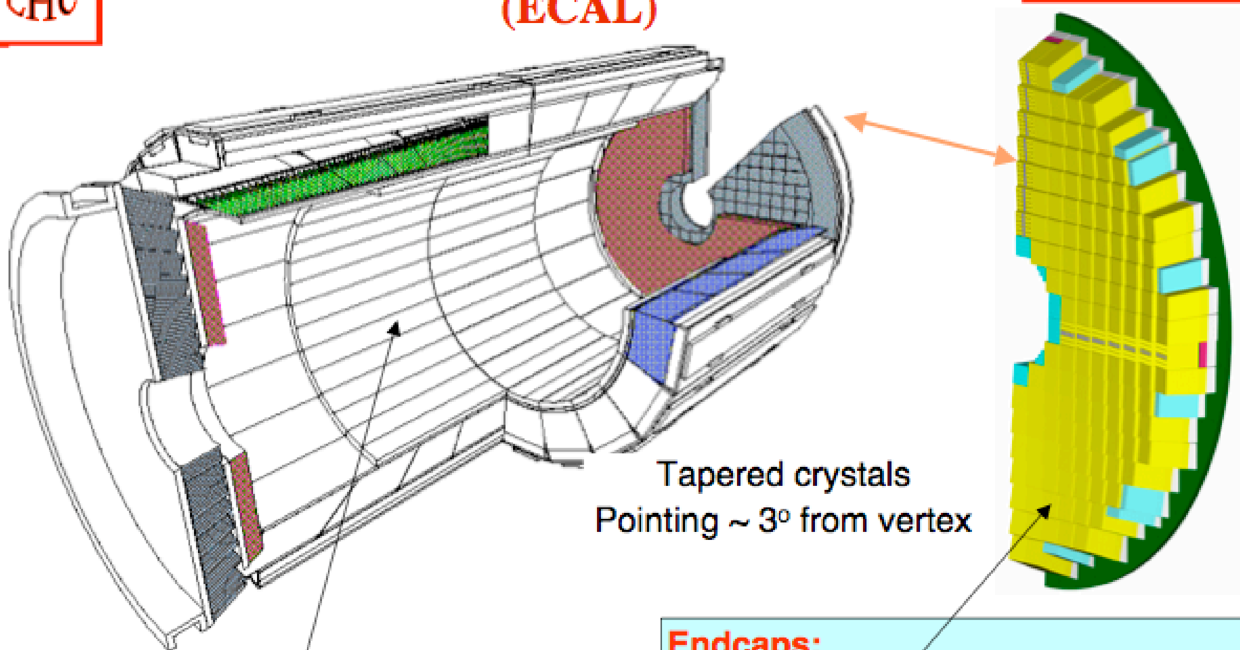






From ECAL…Orientation (Hirosky)

The CMS Electromagnetic Calorimeter (ECAL)



Barrel:
60,000 Crystals
Readout: Avalanche Photodiodes

Endcaps:
4 Dees (2 per endcap)
14648 Crystals
Readout: Vacuum Photodiodes(VPT's)

From ECAL…Orientation

ECAL Take away messages

It appears that after 500 to 1000 fb^{-1} the forward ECAL will require major refurbishing to complete replacement.

Appears that hadronic radiation damage is irreparable
EM damage may be fixed by "bleaching". Studies underway

R&D on rad hard crystals is underway; results promising

Activities: New beam test studies of rad damage effects
Beam tests of Molybdenum loaded $PbWO_4$
New crystals LYSO,LYO, CeF_3

R&D on rad hard photo-detectors proposed

Candidates: GaAr and GaInP photodetectors;
on paper promising -orders of magnitude more radiation hard than silicon.

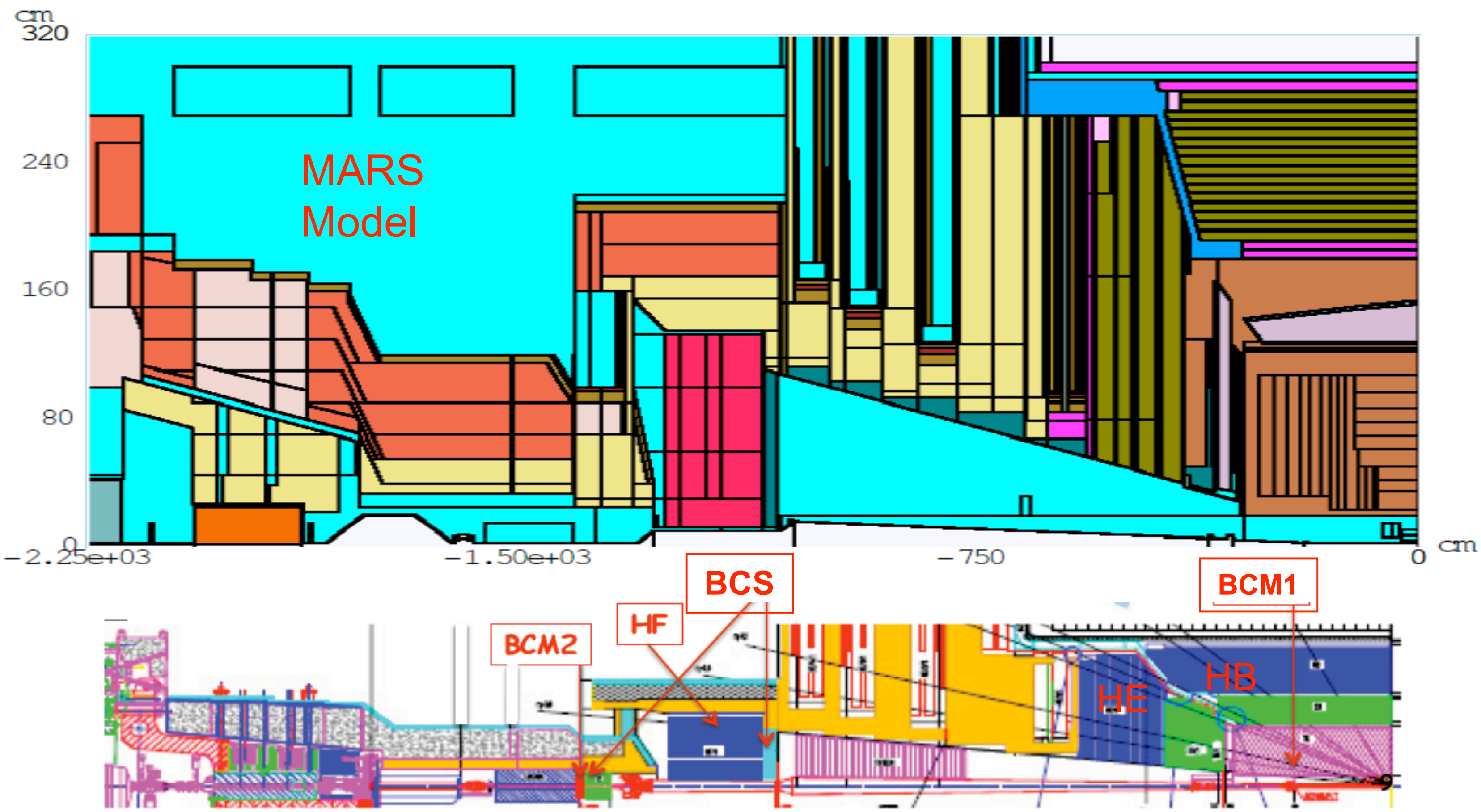
Physics Drivers
(Landsberg, Neu)

- LHC → SLHC upgrade offers *limited increase in reach in a* number of new physics models (~20-50% in terms of mass/energy scale)
- In most cases the objects to be studied are heavy and decay into *very energetic central leptons/jets, thus not very* sensitive to pile-up effects
- EB/HB technology is *reasonably adequate for signal*detection; however the HO importance will increase
- Higher longitudinal segmentation in HCAL may help as well
- Mind the gap! Gap between barrel and end-caps may result in serious deterioration in MET capacities
- While for many new phenomena calorimeter coverage up to $|\eta| < 2.0$-2.5 is adequate, forward jet tagging is essential for strong vector boson scattering studies and would require extension of *forward calorimetry to* $|\eta| \sim 3.5$

Radiation Issues – MARS studies (Bhat, Mokhov)

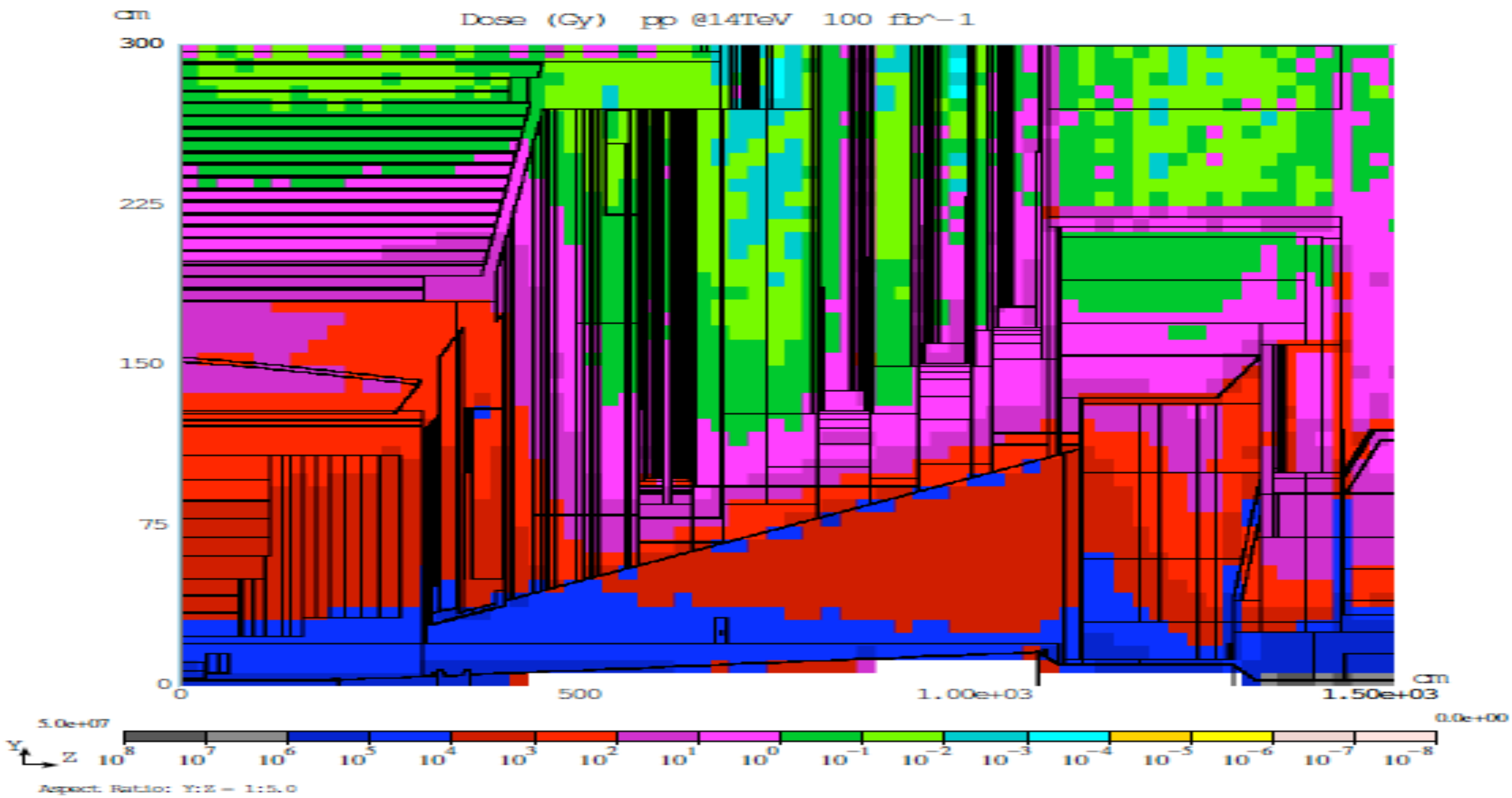
- Latest round of efforts
  - Started in 2007, to re-evaluate beam-induced radiation in CMS, particularly in the pixel detector due to concerns of safety in typical beam-accident scenarios
- Scenarios Studied
  - pp collisions at $L=10^{34}$ $cm^2 sec^{-1}$
  - Machine-induced Backgrounds: beam-gas, beam halo
  - Beam Accidents (potentially the most risky)
- Simulation Results: Maps and tables of radiation dose, particle fluence, energy spectra are available. Results in (r,z) stored in a database. Web Tool exists to extract numbers. Over a dozen presentations given at CMS mtgs.
- CMS Notes: CMS CR-2009/262 (pp results conf rep for tracker)
  CMS Note-2009/000 (Beam accident studies)
- Detailed CMS Note on pp results in preparation

Mars Model



cm
320
240
160
80
0
MARS
Model
-2.25e+03
-1.50e+03
-750
0
cm
BCS
BCM1
HF
BCM2
HE
HB

Maps of radiation dose



Radiation Issues

- Take away messages
  - Extensive radiation simulations have been done for the CMS detector, over the past few years using MARS15.
    - pp at 14 TeV, 10 TeV, 3.8T, 0T
    - preliminary beam-gas, beam-halo
    - Beam accidents
  - Lots of results and tools exist
  - It is possible to enter coordinates, parameters, and it returns dose
  - Further effort needed to study activation.

Testing facilities (Ramberg, Kubota, Adams, Sulak)

- Take away messages on Test Facilities

  - Fermilab has several test beam spigots in the meson lab with a new addition that will allow hadronic irradiation of detector elements at levels of $2x10^{11}$ protons/cm^2 per minute. This should add to the options for high intensity hadron irradiation.

  - For radiation damage studies of electronics both PSI and Florida State have adequate facilities. FSU is very attractive since it is free but infrastructure is not presently existing (turn key DAQ for users, radiation handling facilities, etc. This should be pursue since it offers a low cost option which has more intensity than PSI.

  - Several high intensity hadronic options were presented buy Y. Kubota. Table on the next page

High Intensity Proton Test Beams

	Indiana Cyclotron	Mass General Hospital	TRIUMF	CERN PS
price	\$627/hour	\$650/hour (only beam-on time)	\$450 per hour[1]	Free?
flux	50nA during day[2]	total flux 100 nA ($6x10^{11}$ p/s) [3]		10^{13}-10^{14} p/hour
beam energy	200 MeV	200 MeV (650 MeV/c)	up to 500 MeV	up to 40 GeV
range[0]	4-7 cm	4-7 cm	>23 cm	large
lead time	typically a month	4-6 weeks typical	last one was Sept 09	June/July 2010
schedule	throughout year	throughout year	once a year	No LHC runs
cool off	cannot estimate!	1-3 weeks typically[5]	Worrisome issue	

[0] Except CERN PS, only one crystal can be irradiated at a time.

[1] including beam tuning, energy changes and any equipment set-up time

[2] 100nA off hours

[3] w/ 50% efficiency of scattering, 15cm dia can be covered with $2x10^9$ p/s/cm^2

[4] may be longer for Pb;

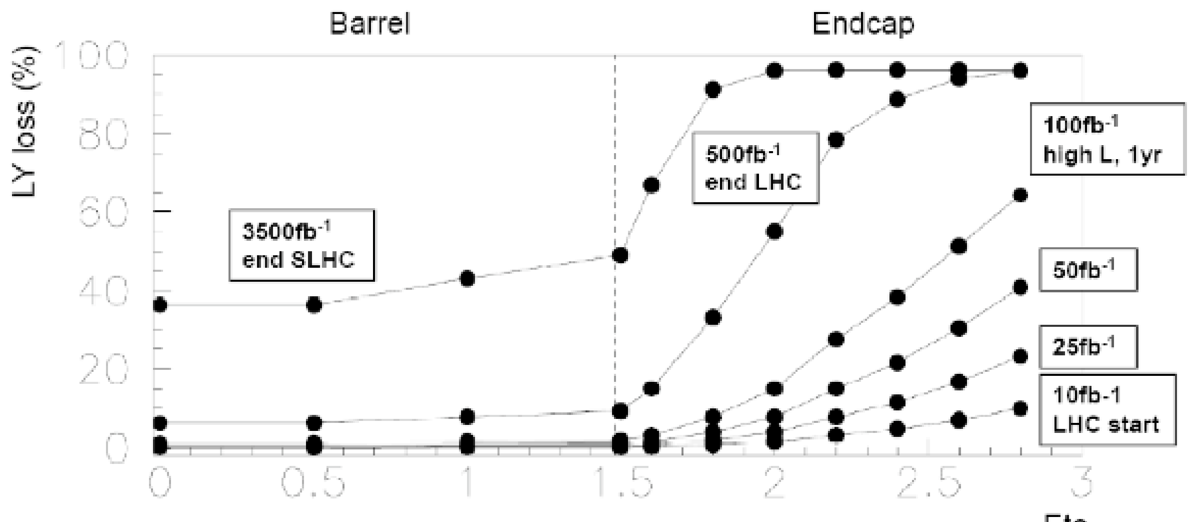
ECAL R&D
(Dissertori, Singovski, Gatoullin, Neu)

- **LHC era:**
  - L_{inst} up to 10^{34} /cm^{2}s, L_{int} up to 500/fb
- **SLHC era:**
  - L_{inst} up to 10^{35}/cm^{2}s, L_{int} up to 3-6k/fb
  - Very challenging particle detection, acquisition and reconstruction environment
- **ECAL endcaps will need replacement for SLHC era:**
  - **At end of LHC era** >50% dark beyond |η|=2.0
  - New detection medium, new photodetectors, new front end, new geometry possibly

Expected performance of present ECAL EE

Effects Of light Attenuation

No photodetector or electronics degradation



Motivation for searches for new rad hard crystals and photodetectors for ECAL

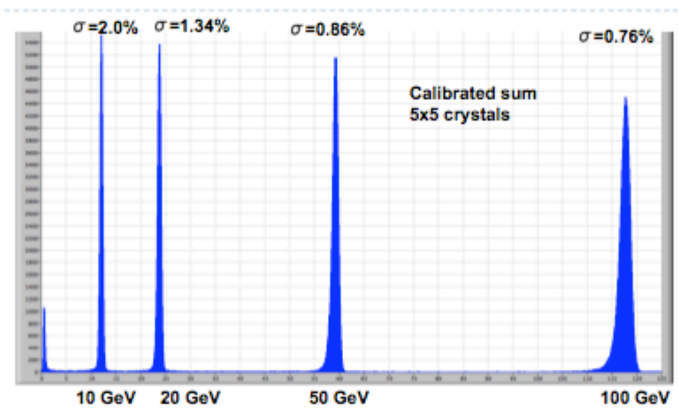
ECAL R&D I

- Take away messages

- Results from new studies of radiation damage in **existing $PbWO_4$** were presented. Both hadronic and electromagnetic were studied to validate previous results.

Preliminary Results

Interpreted as surprisingly small loss of resolution for Irradiation up to 10^{13} p/cm^2 for $H \rightarrow \gamma\gamma$



!Still far from the optimal performance (sigma 0.61% at 100 GeV)

!Resolution degradation at low energies

!No significant degradation at 100 GeV

	10 GeV	20 GeV	50 GeV	100 GeV
Matrix1: Production xtals	2.00	1.34	0.86	0.76
Matrix2: Proton irradiated xtal at the center	2.74	1.61	0.89	0.66
Matrix3: central 3x3 of Proton and gamma irradiated xtals	2.85	1.96	1.20	0.77

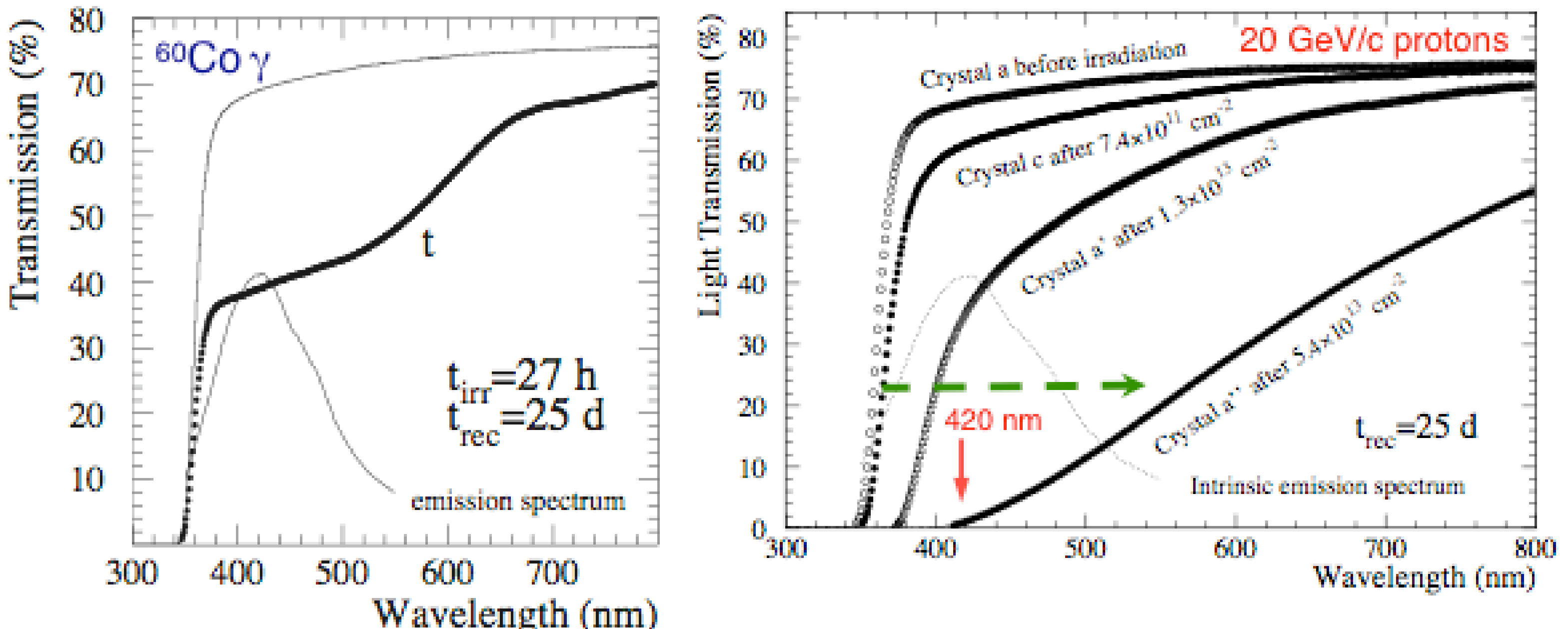
Photo statistics contribution:

$$a_{pe} = \sqrt{\frac{F}{N_{pe}}}$$

N_{pe} ! 4000/GeV	for matrix 1	1.7%	3.1%
2000	for matrix 2	2.4%	4.5%
1000	for matrix 3	3.1%	6.3%
		F = 1.2 for good PMT	F=4 for VPT

ECAL R&D II

PbWO$_4$ irradiation



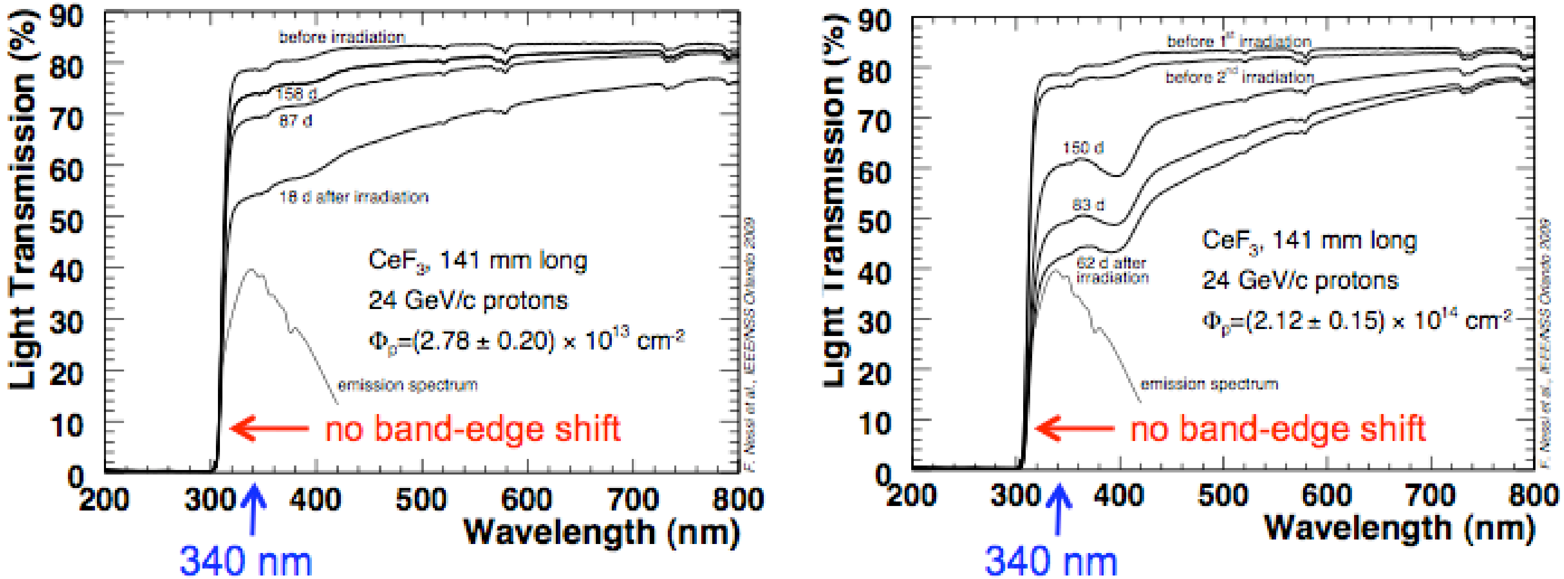
→ It induces changes in Light Transmission, qualitatively different from those caused by γ radiation

Hadronic radiation appears to damage the crystal structure in an irreversible way (without heating the crystal). This damage results in decrease in light transmission.

ECAL R&D III

CeF_3 Features except that there is no band-edge shift but some recovery

important recovery over a few months



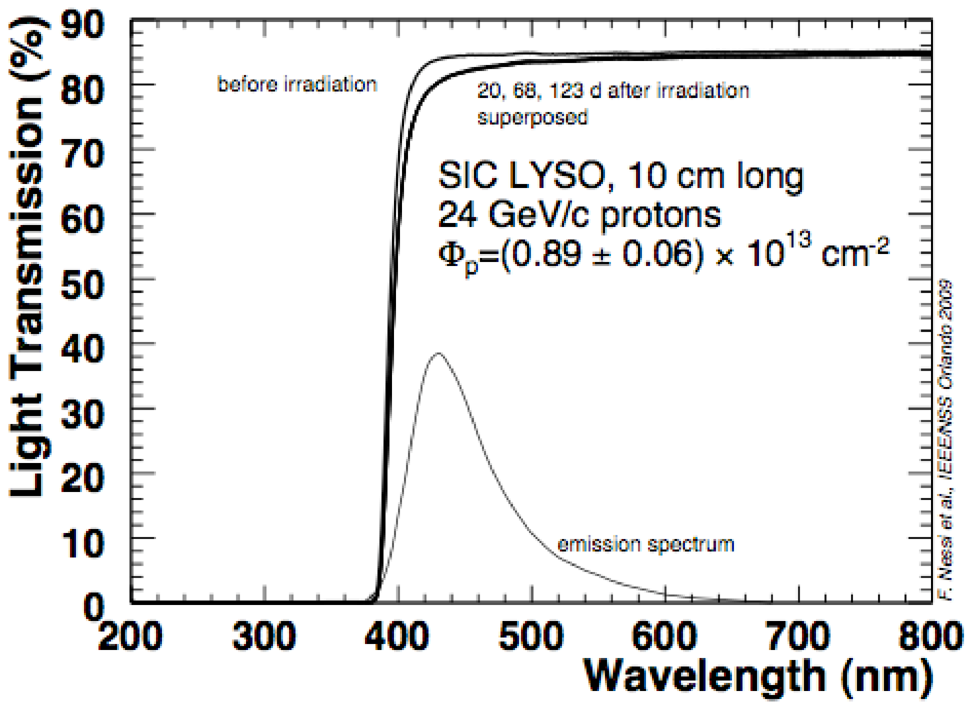
→ light transmission recovers for all λ, except for an absorption band that seems cumulative, sitting however where the emission drops off.

→ evaluate damage further at the peak-of-emission λ = 340 nm

Once again, appears hadronic damage is due to nuclear "stars"

ECAL R&D IV

LYSO has the best characteristics;
Higher irradiations needed; no recovery seen so far



→ The change in Transmission induced by p-irradiation at this fluence in LYSO is quite modest
→ No recovery overall is observed between 20 days and 123 days after irradiation

ECAL R&D V

- A hadron-specific, cumulative damage from charged hadrons has been observed in $PbWO_4$, which only affects light transmission. All characteristics of the damage are consistent with it being mainly due to an intense local energy deposition from heavy fission fragments.
- Measurements of proton-induced absorption up to $\phi_p = 2 \times 10^{14}$ p/cm^2 in CeF_3 show a damage which recovers at room-T and is not cumulative
- Measurements of proton-induced absorption in LYSO show a damage which does not seem to recover at room-T, but is a factor 5 times smaller than in $PbWO_4$ for $\phi_p = 0.9 \times 10^{13}$ p/cm^2.

  Proton irradiations will be performed at higher fluences:

  → they should allow establishing whether the damage is cumulative in LYSO
- The absence of a dominant Rayleigh-scattering component in CeF_3 and LYSO is consistent with its presence in $PbWO_4$, due to highly-ionizing fragments and their strain fields coming from the fission of Pb and W.
- Our measurements demonstrate that crystals exist, which are suitable for precision calorimetry in high fluences of energetic hadrons, as expected at superLHC
- Hadron damage is not entirely about color centers. It is also about nuclear interactions and displacement of atoms!

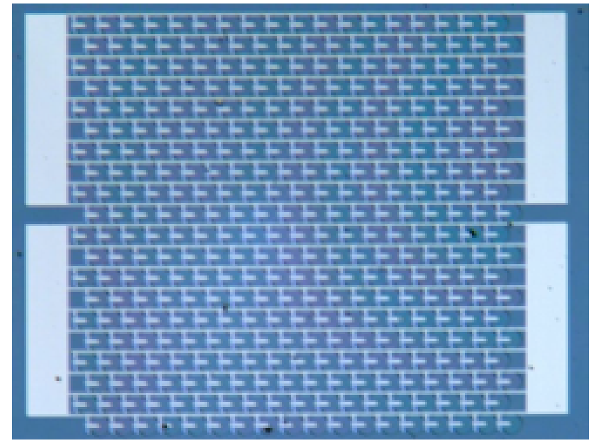
ECAL R&D VI

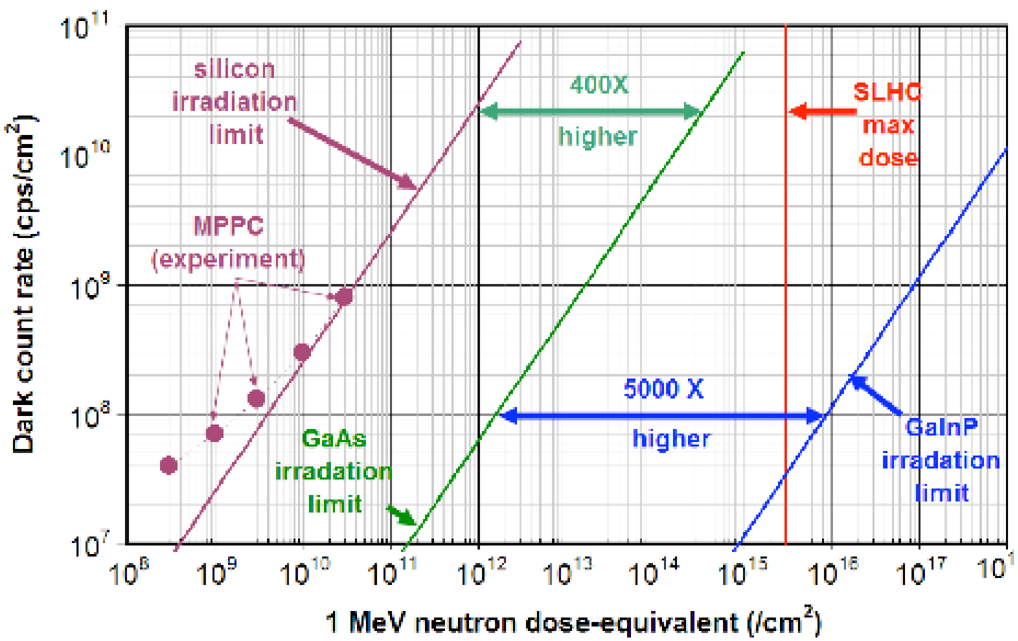
What about radiation hard semiconductor photodetectors to replace VPTs?

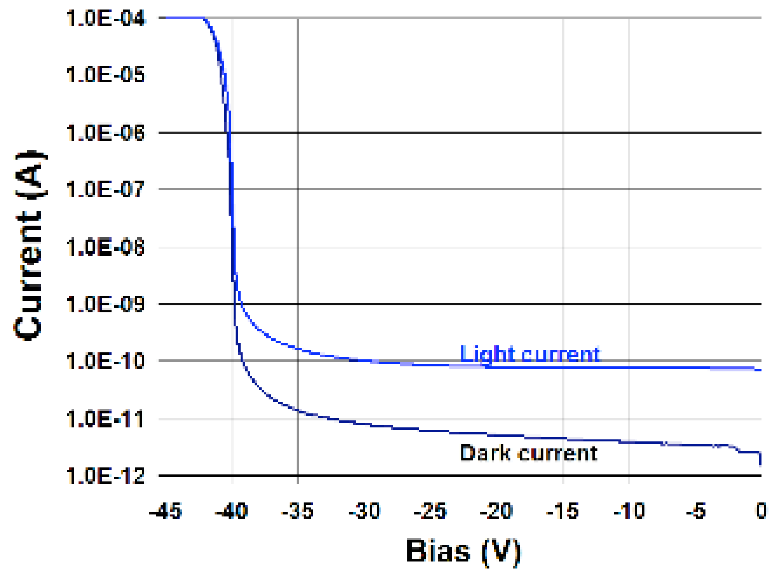
Candidates: GaAs and GaInP Geiger mode photodetectors

Appear to be orders of magnitude more robust against radiation damage

1 mm² GaAs wafer







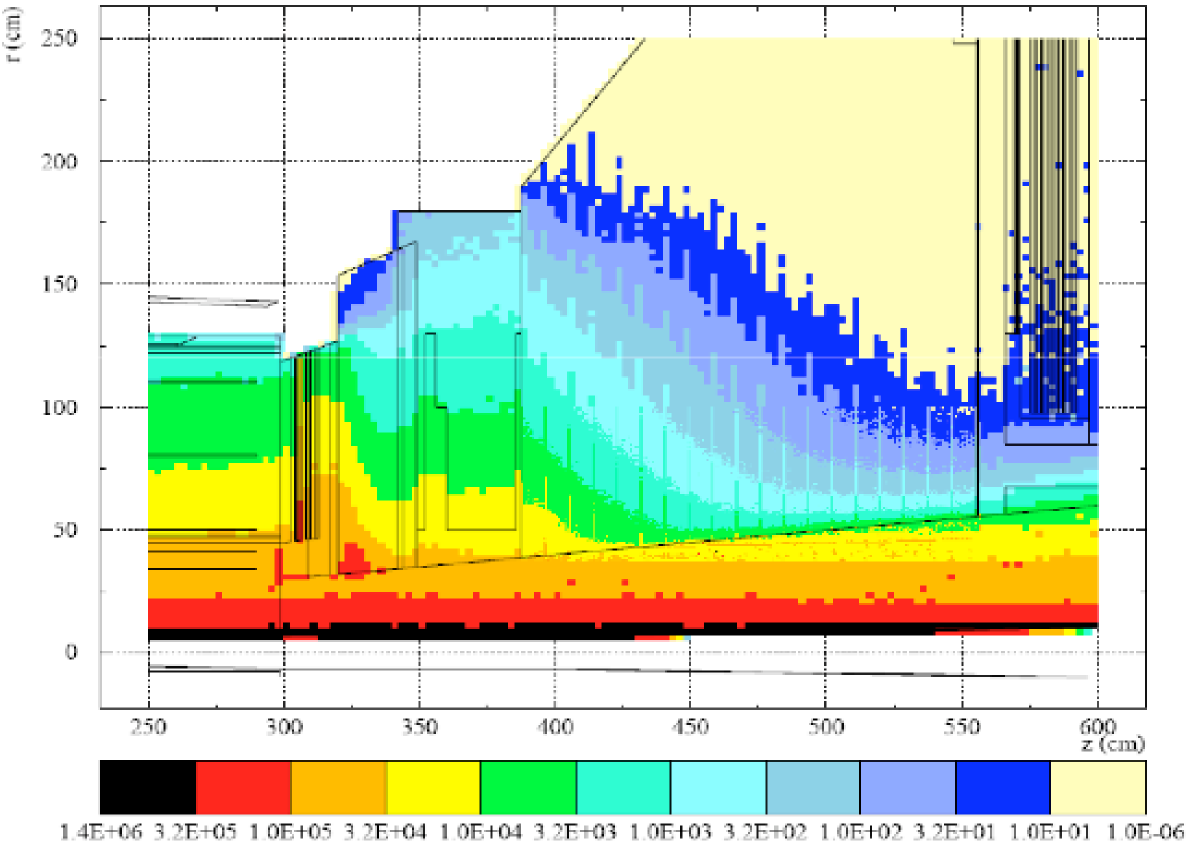
Geiger curve

HCAL R&D
(Onel, Bilki, Akchurin, Penzo, Norbeck)

- A variety of technologies
  - Quartz tiles with waveshifter (HE)
  - Digital calorimetry (HE)
  - Gas calorimetry, PPAC (HE)
  - Quartz and scintillator to improve e/h (HE)
  - Liquid scintillator in quartz tubes (HE/HF)
  - QQ fiber (HF)
  - Several others to follow up - at next meeting…

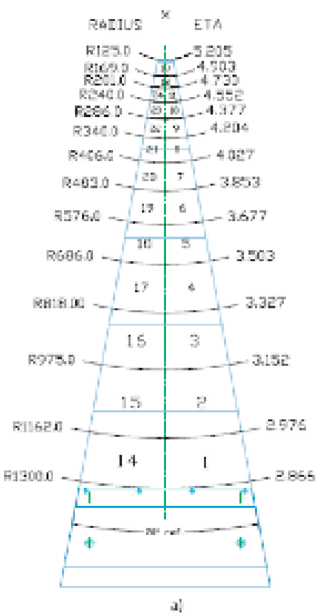
HCAL R&D

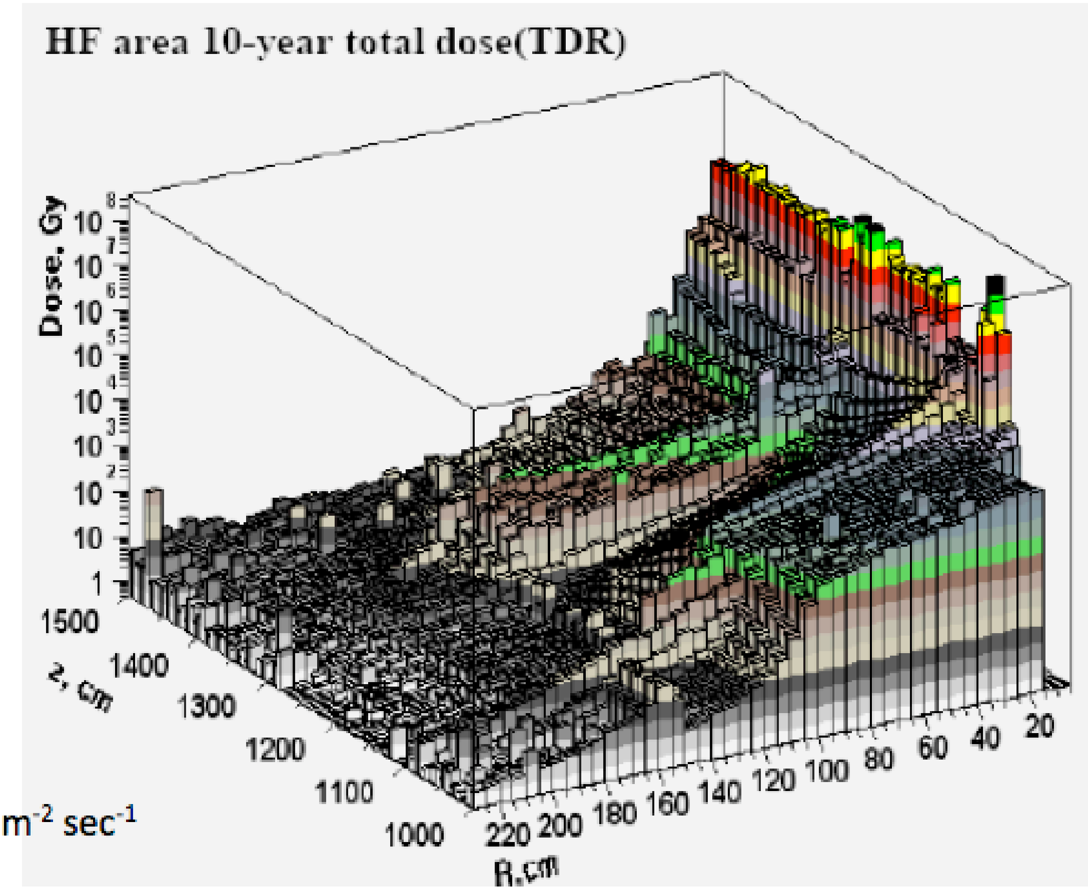
The radiation map of HE calorimeter, Huhtinen et al. (CMS IN 2001/050)
10 years at L = 10^{34} $cm^{-2}s^{-1}$ luminosity is assumed, the units are Gy



HCAL R&D

Meanwhile what is cooking at HF…





10 years at L = 10^{34} cm^{-2} sec^{-1}

HCAL R&D
(Onel, Bilki, Akchurin, Penzo, Norbeck)

- Take away messages
  - HE inner layers (lowest r, z values are vulnerable in the 3-5 Mrad range
  - HF QP fiber vulnerable (approaching 1 Grad)
  - There are subtleties for transporting optical signals and readout
  - Need to consider the combined endcap/forward system

Toward a Schedule For a TDR

Item	Necessary Time
• Physics Drivers	3+1 months
• Simulation Tools	3+3 months
• Detector Performance	12+6 months
• Simulation Studies of Designs and Performance	24+12 months
• R&D Methods and Tests	24+12 months
• TDR Preparation	6+3 months

Potential 2010 ECAL-HCAL Task Force Meetings

Upgrade Weeks

26 - 30 April

25 - 29 October

Upgrade Days

21 Jan
18 Feb
24 June
15 July
30 Sep
18 Nov

We will next meet during Dec. CMS Week

Possible Task Force Meetings

During Upgrade Weeks

28 April*, 27 October*

During CMS Weeks

Dec 6*, March 15*, June 14*, Dec 6*

In coordination with Upgrade Days

20 Jan
19 Feb*
23 June
14 July
29 Sep*
17 Nov

* Suggested meeting dates

Conclusions from general discussion (all participants)

- Take away messages:
  - This was a get acquainted meeting.
  - Follow up needed – both subgroup organization and overall planning.
    - December CMS Week is next opportunity
  - Upgrading of the calorimetry needs continuous scrutiny and planning and preparation needs to be underway
    - Needs to map onto the (evolving) LHC schedule