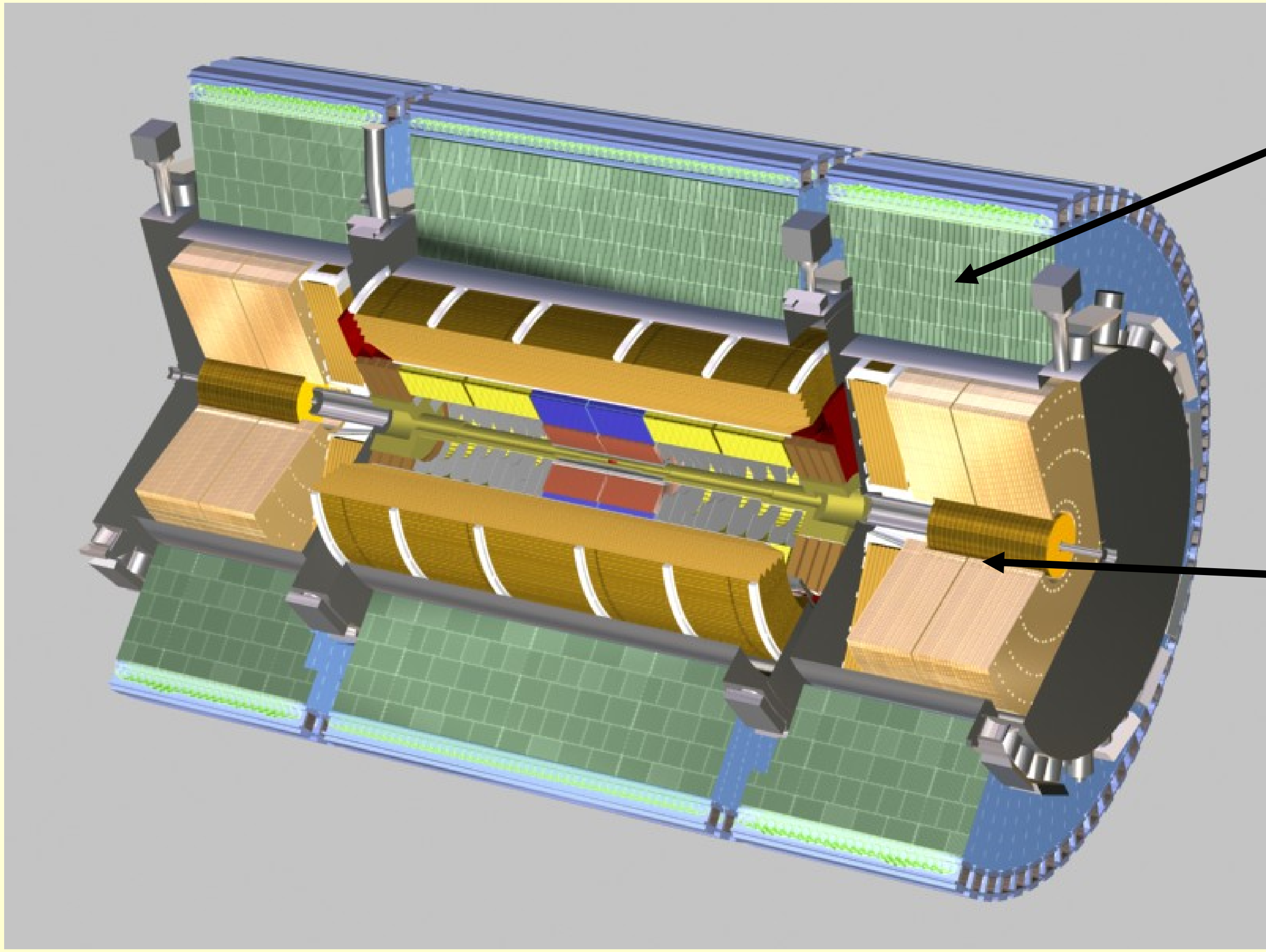
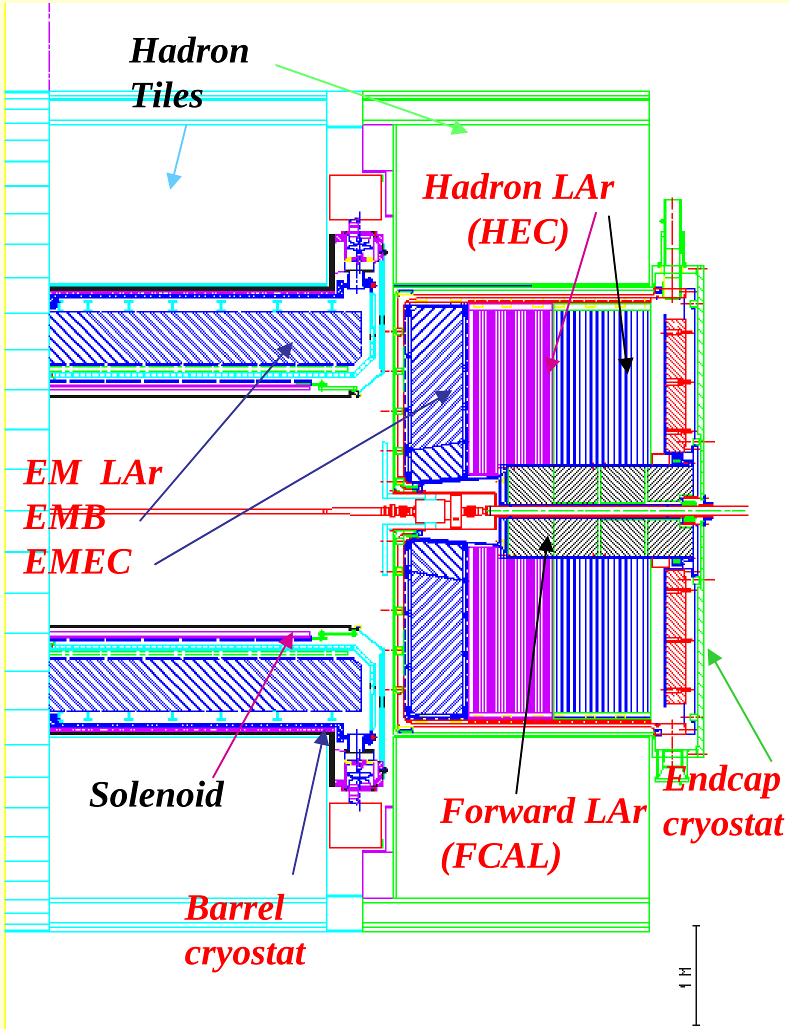
Calorimetry at sLHC

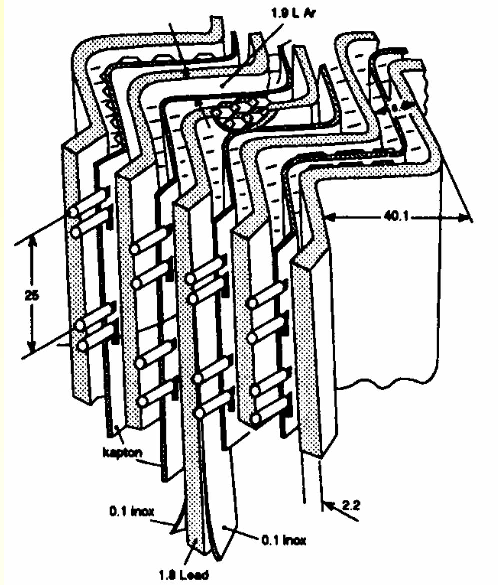
- Brief description of the calorimeters in
  - ATLAS
  - CMS
- Boundary conditions for sLHC
- Plans for calorimeter upgrades at
  - ATLAS
  - CMS
- Summary

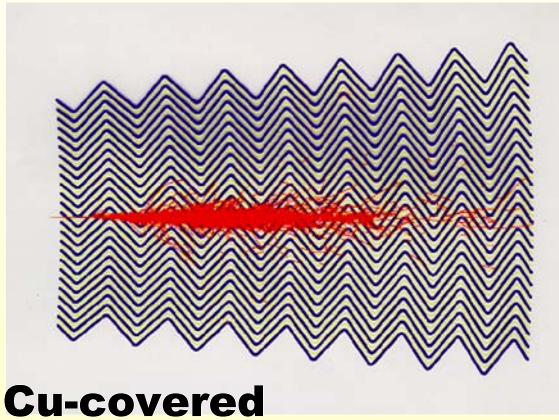
Calorimeters in ATLAS



LAr Calorimeters

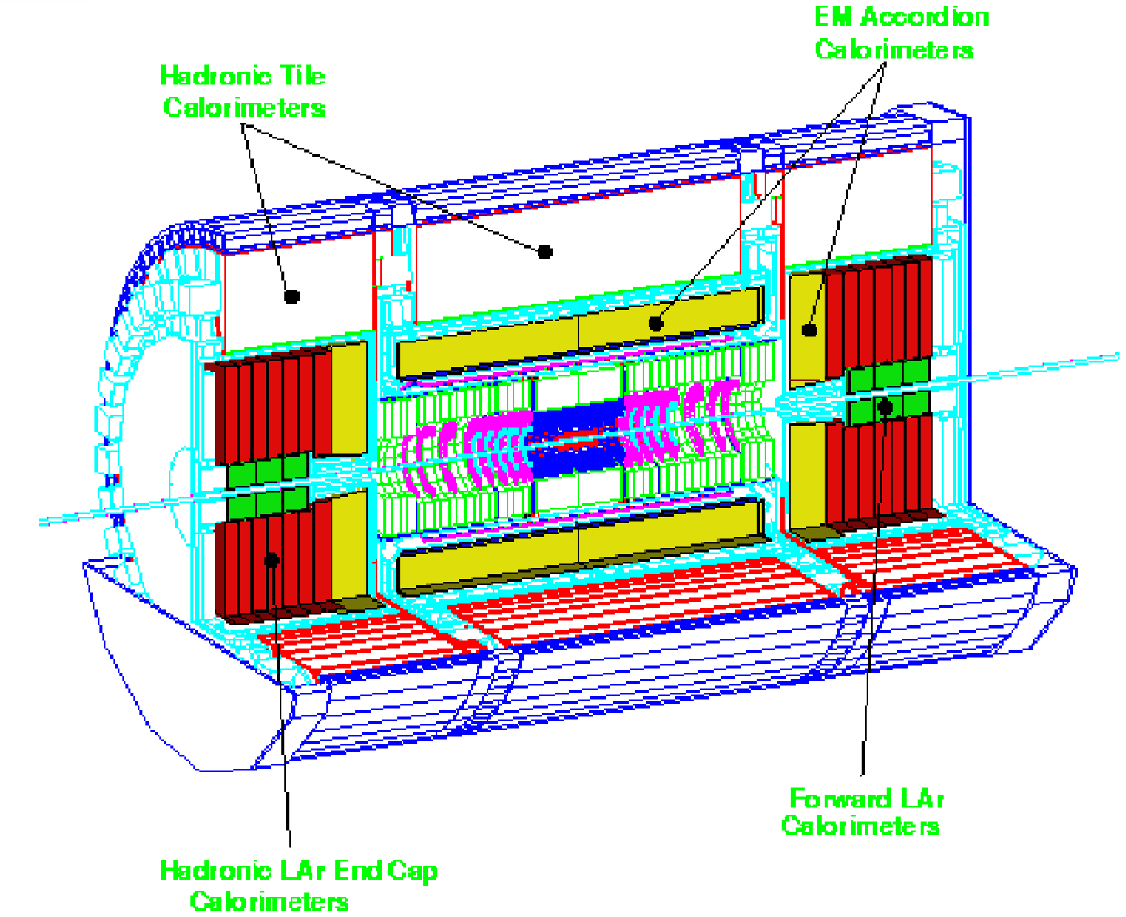




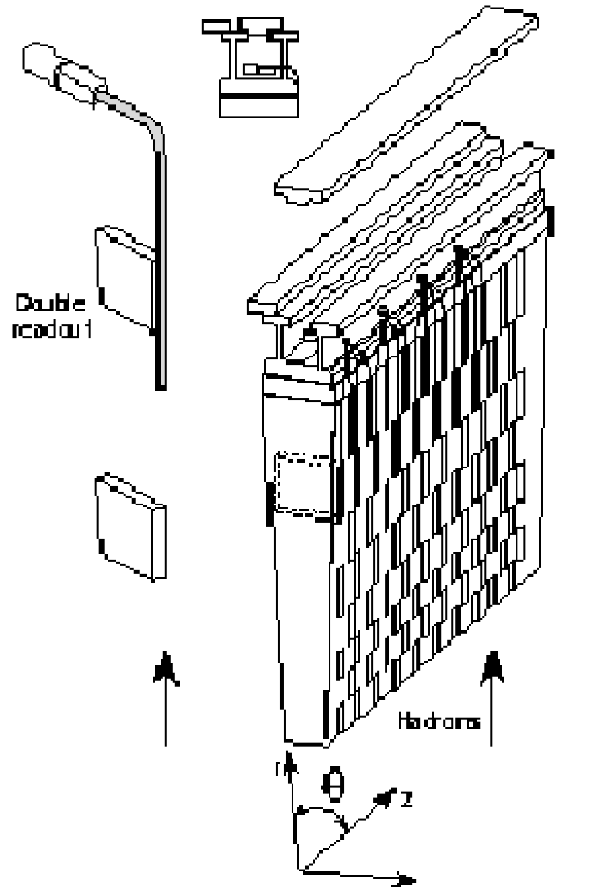


Absorber: Pb / Fe / Cu , multi-layer readout boards Cu-covered

Hadronic Tile Calorimeter

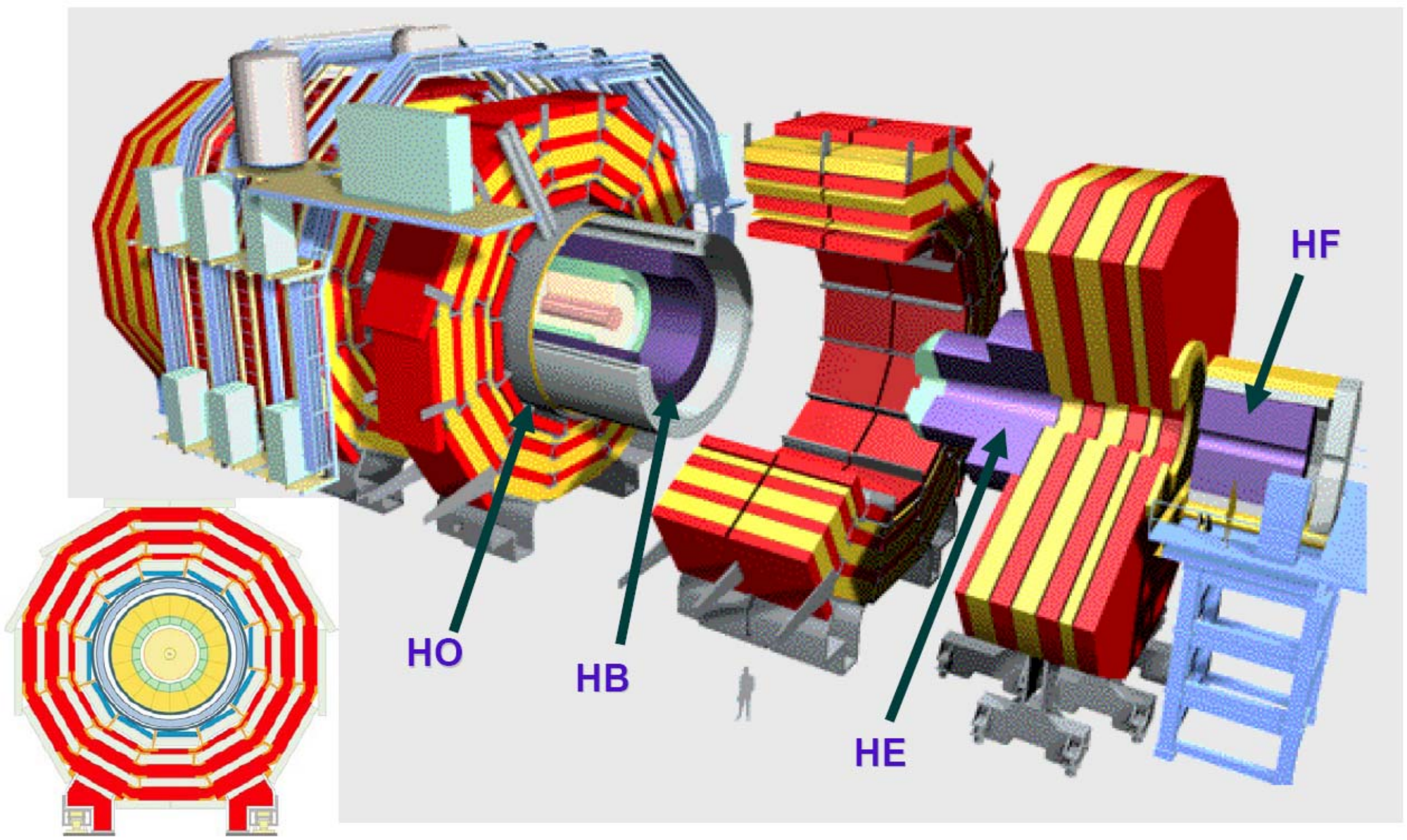


Tilecal Design:

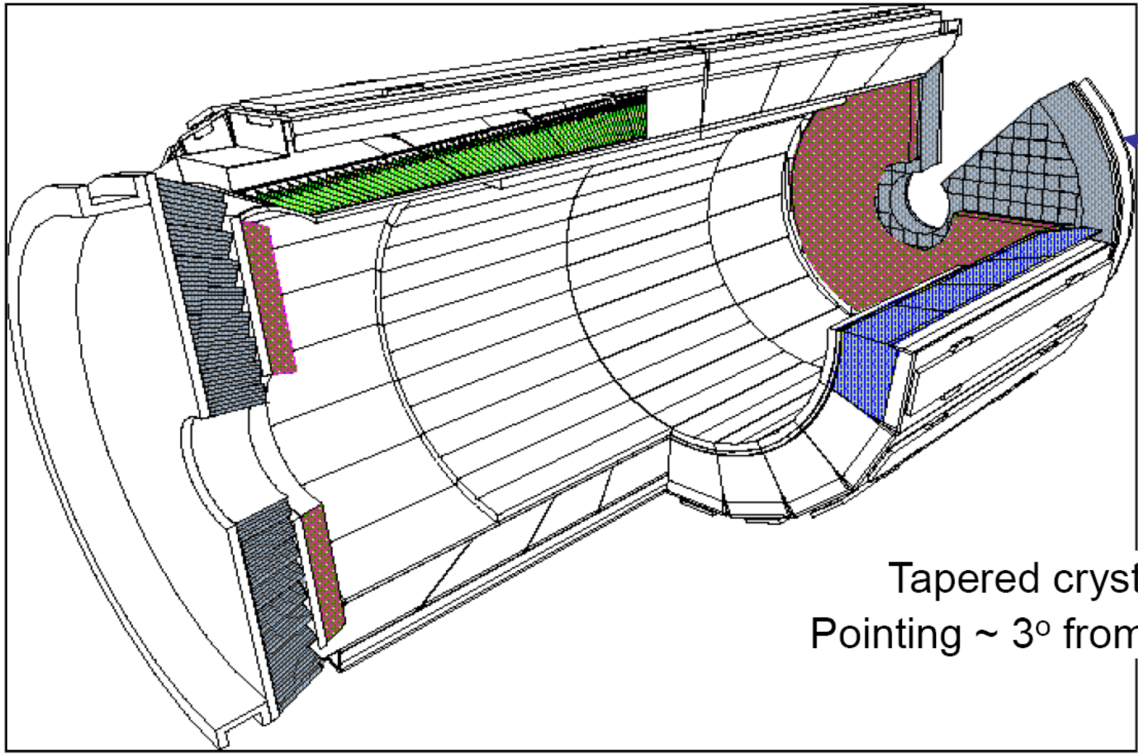


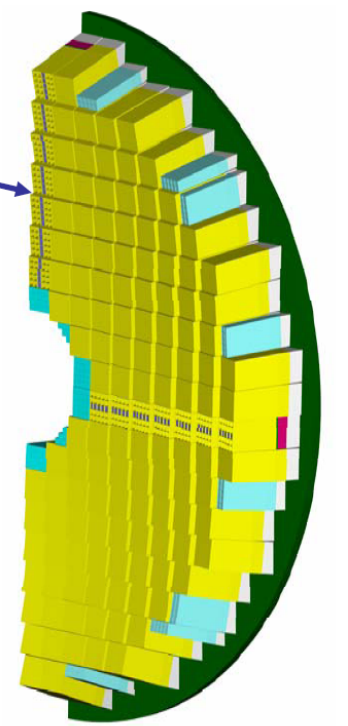
Sampling Calorimeter with Fe / Scintillator

Calorimeters in CMS



CMS ECAL PbWO$_4$ Crystals





Barrel:
36 Supermodules (18 per half-barrel)
61200 Crystals
Total mass 67.4 t

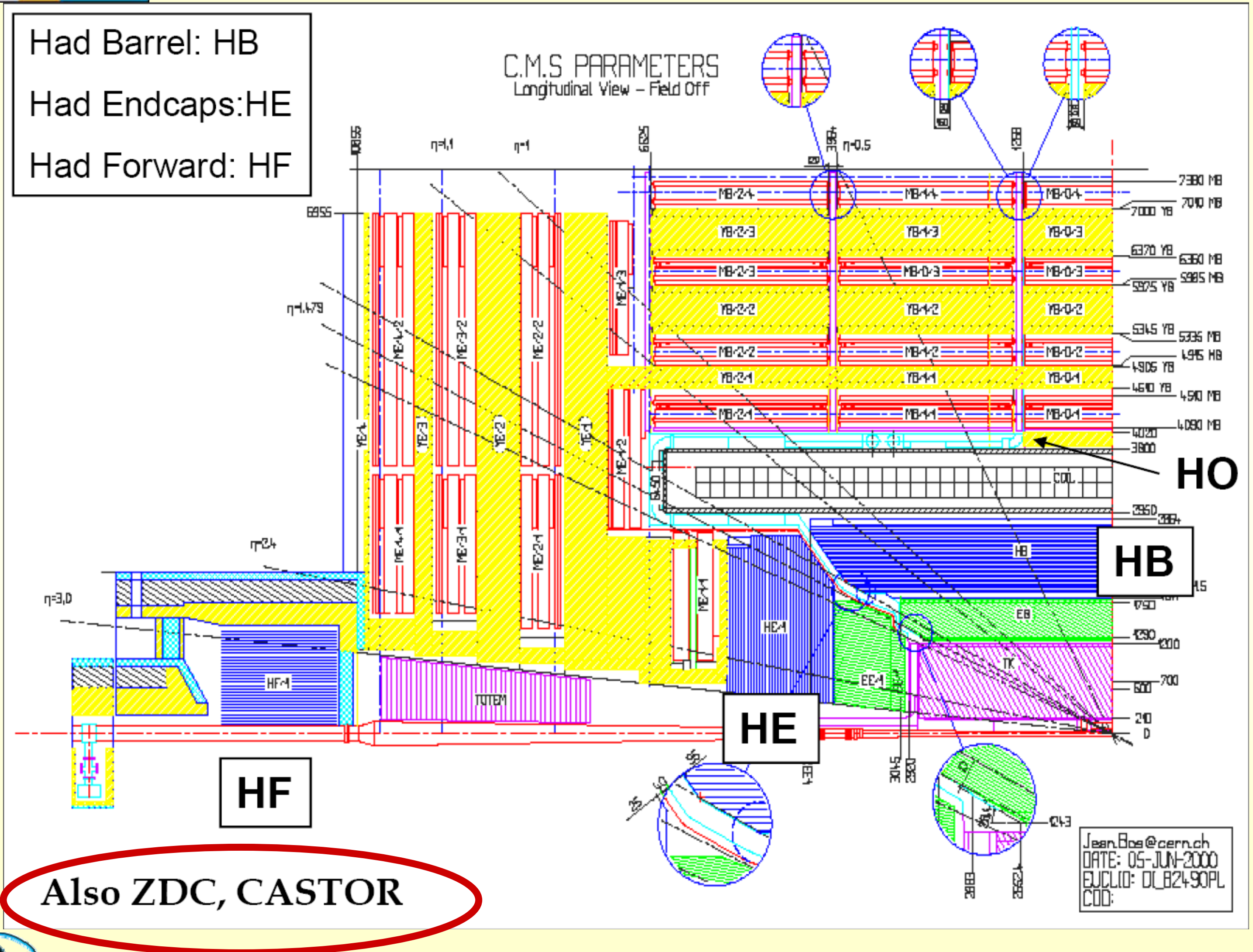
Endcaps:
4 Dees (2 per endcap)
14648 Crystals
Total mass 22.9 t

CMS HCAL

Had Barrel: HB

Had Endcaps:HE

Had Forward: HF



Absorber: Cu sandwiched between outer layers of Fe

HB, HE, HO: Scintillators

HF: quartz-fibers → more radiation hard & compact showers

CASTOR &ZDC:

W /Q-plate(fibres)

Expectations for sLHC

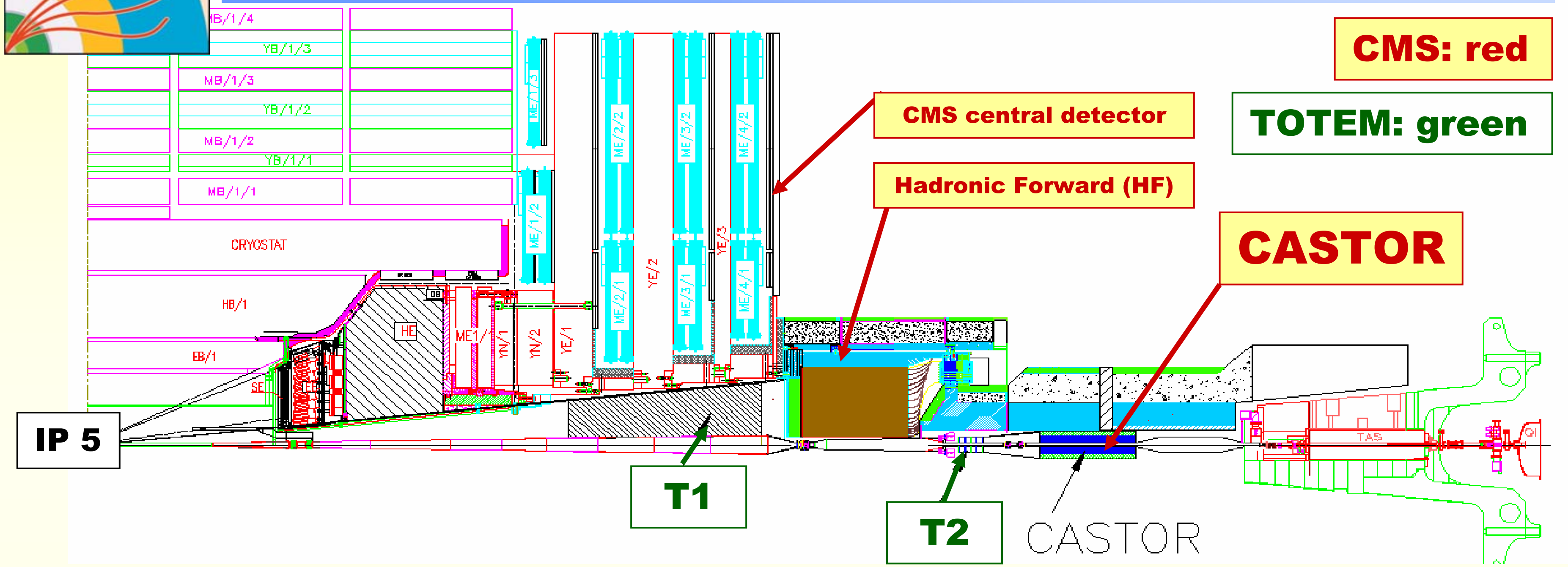
Calorimeters are usually designed as stable detectors, which give a fast input to the trigger

→ In first order no special worry for the barrel regions, maybe some changes for the readout electronics are needed.

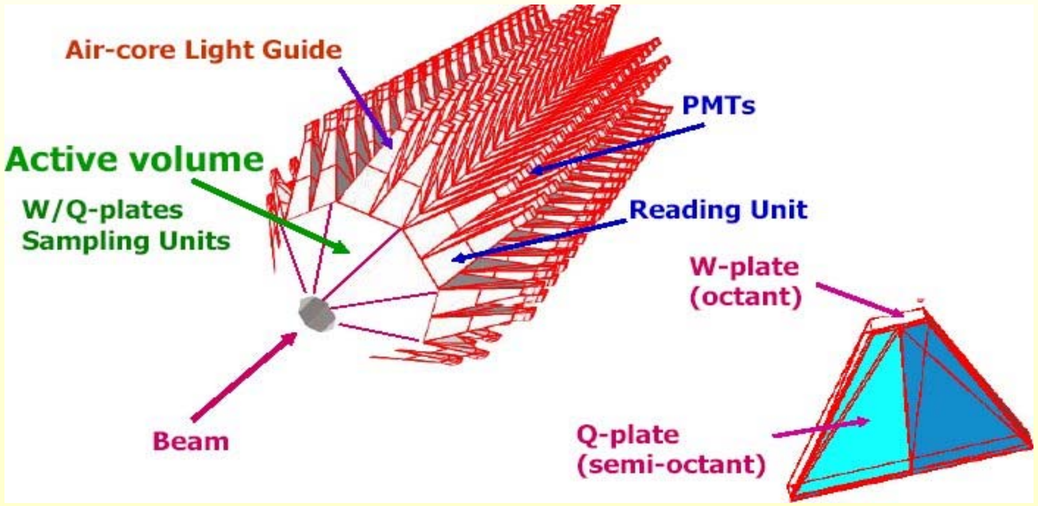
Closer to the beam pipe in the forward region
→ high particle fluxes → high occupancy,
→ high radiation level and strong activation
→ difficult to readout and to maintain

Take the CASTOR calorimeter as a template for the study of sLHC conditions.

CASTOR @ CMS



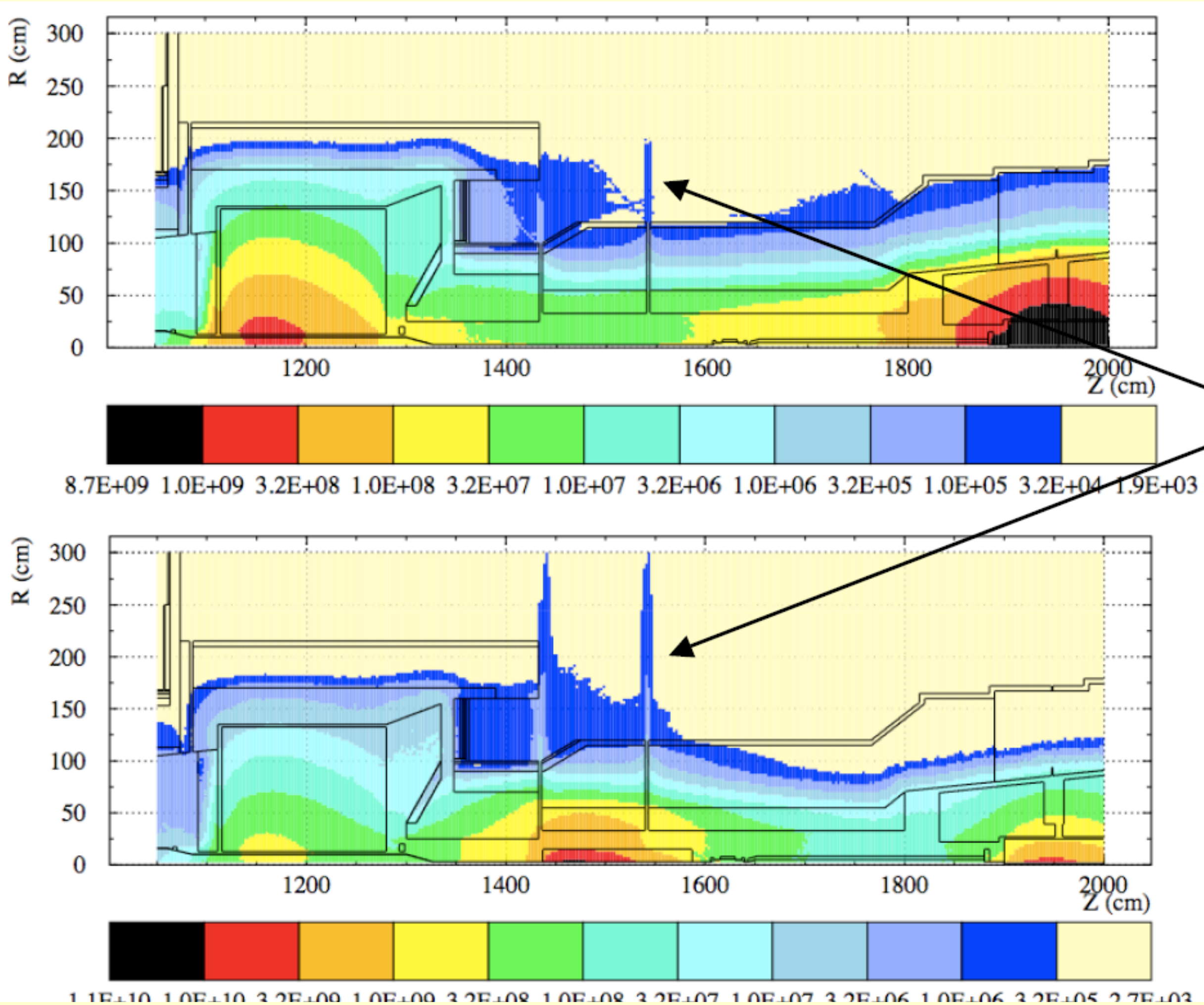
CMS: red
TOTEM: green
CMS central detector
Hadronic Forward (HF)
CASTOR
IP 5
T1
T2
CASTOR
CRYOSTAT
HB/1
EB/1
HE
TAS



Air-core Light Guide
PMTs
Active volume
W/Q-plates
Sampling Units
Reading Unit
W-plate
(octant)
Beam
Q-plate
(semi-octant)

Example: Fluxes (@ CMS)

M.Huhtinen 2006



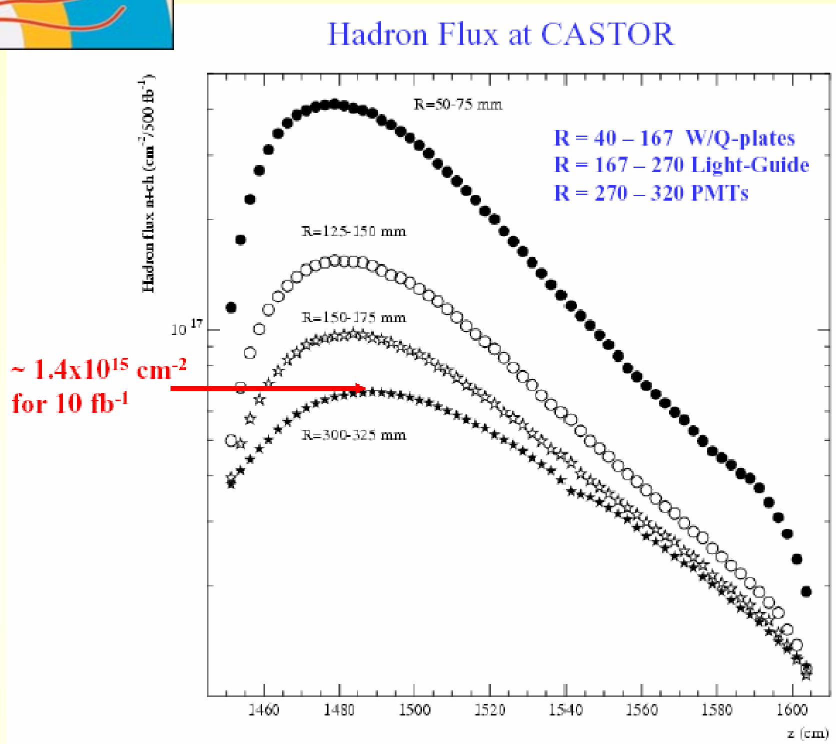
Neutrons/cm²/s at 1E34

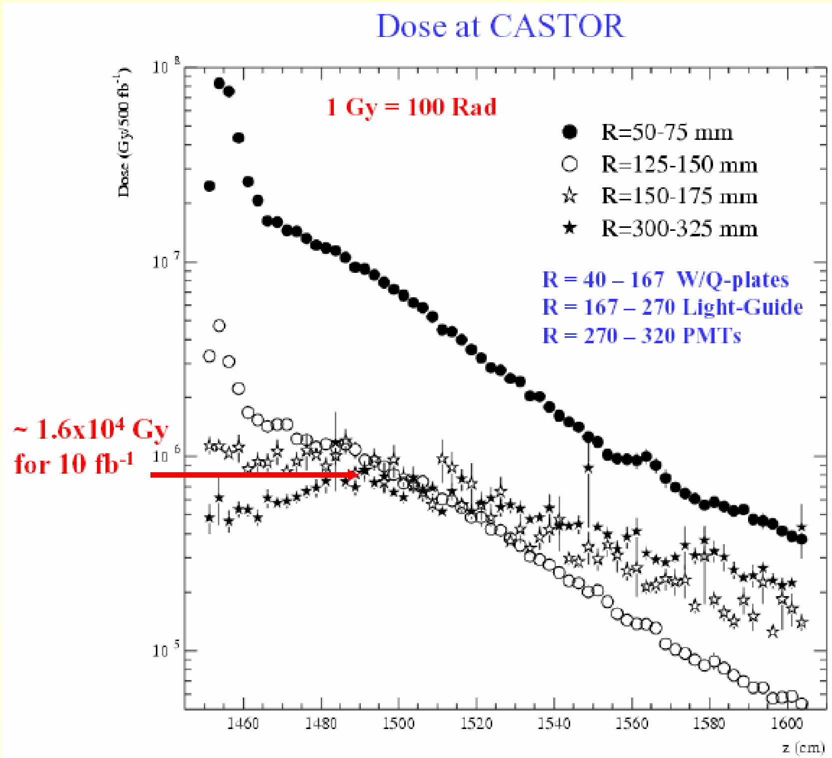
Effect of 30mm gap !

~10 times more with CASTOR

Note shifted scale !

Fluxes in the CASTOR Region





CASTOR can stay in the beam line only up to 2x 10^{33} cm-2 s-1

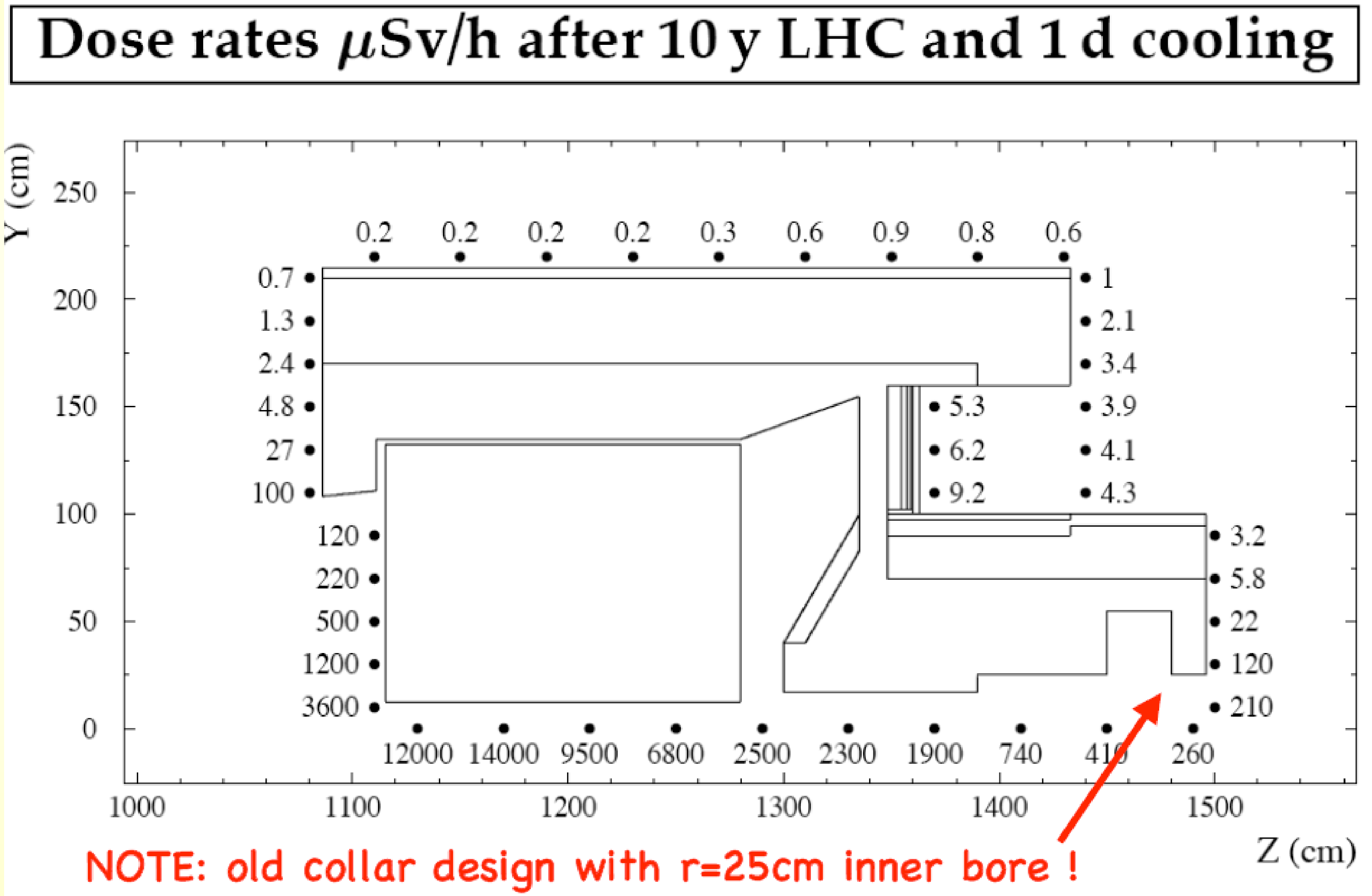
→ numbers for 10y LHC 500fb^{-1} scaled down to 10 fb^{-1}

Maximum Dose up to ~ 2 10^{6} Gy = 200 MRad

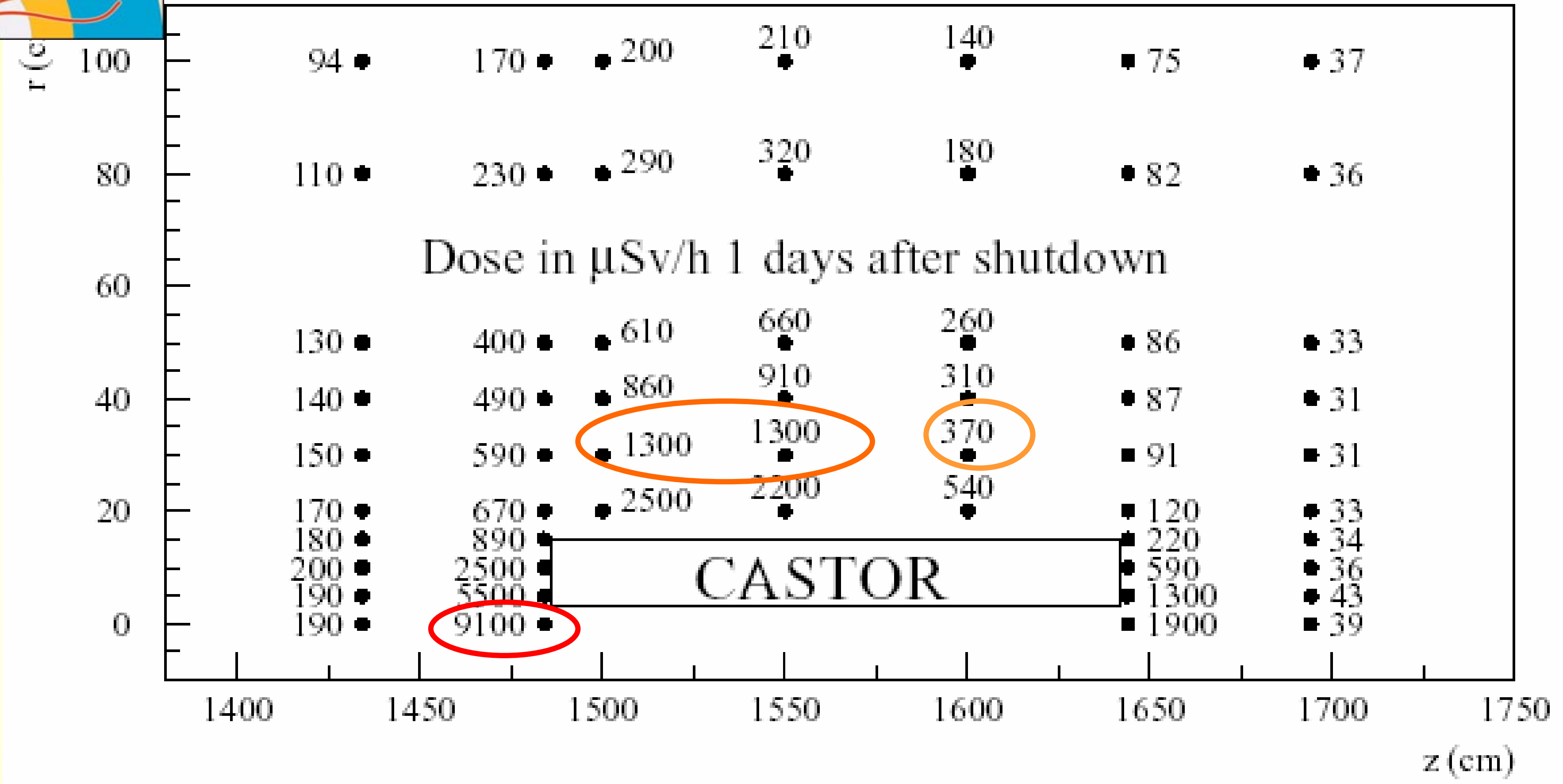
Integrated dose at radius of the PMT's: 1.6 10^{4} Gy = 1,6MRad

Activation @ CMS

M.Huhtinen 2006



Activation in the CASTOR Region



Activation scaled to *L*=2e33, for 10 y running and 1 day cooling

highest activation in front of the calorimeter (9.1mSv/h),

at PMT level (r=30cm): front ~ 1.3 mSv/h , rear ~ 0.4mSv/h

→ Difficult for radiation protection (max. 1mSv per intervention)

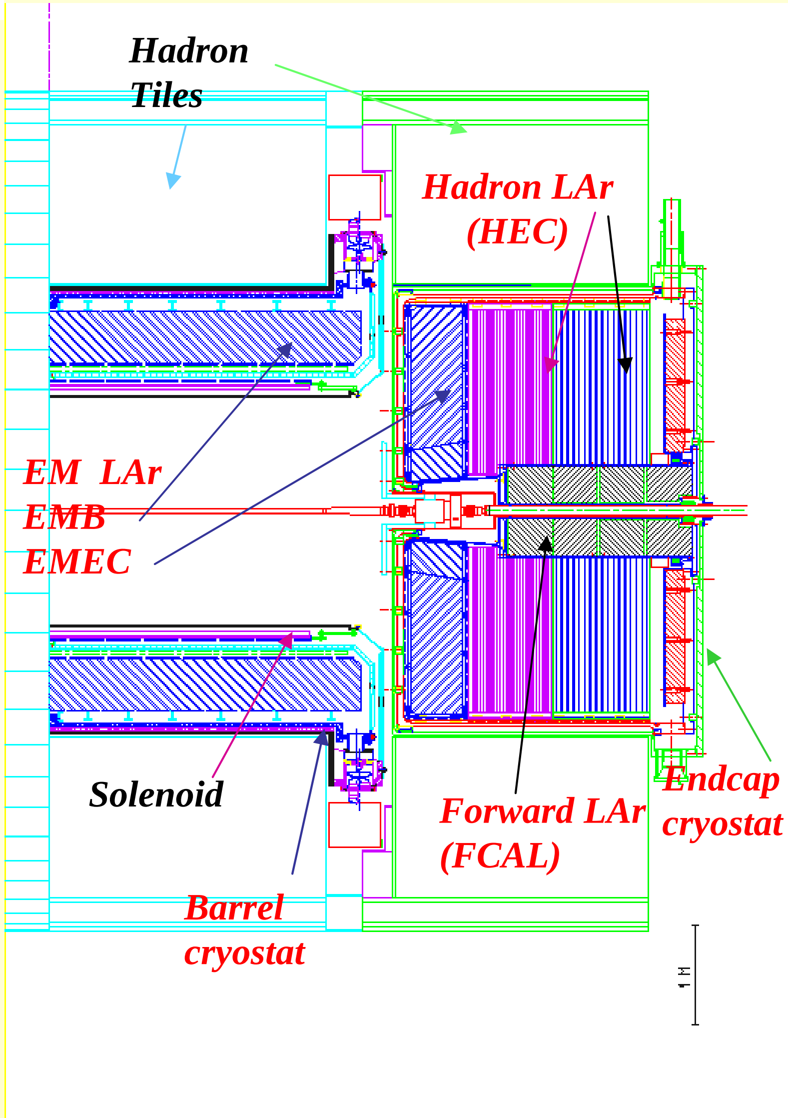
Upgrade Plans

In the past already individual efforts for upgrades were performed also with test beam measurements and irradiation tests of detector components.

Now upgrade plans are taking shape and project proposals are in the process of being written.

In the following only a snap shot of the present developments in ATLAS and CMS.

Upgrade Plans for ATLAS Calorimeters



Particles from min-bias events deposit energy in calorimeters continuously.

High Power density especially in EndCap modules.

This deposited power density drives:

- **HV current draw**
- **Space charge build up**
- **Heat deposit**

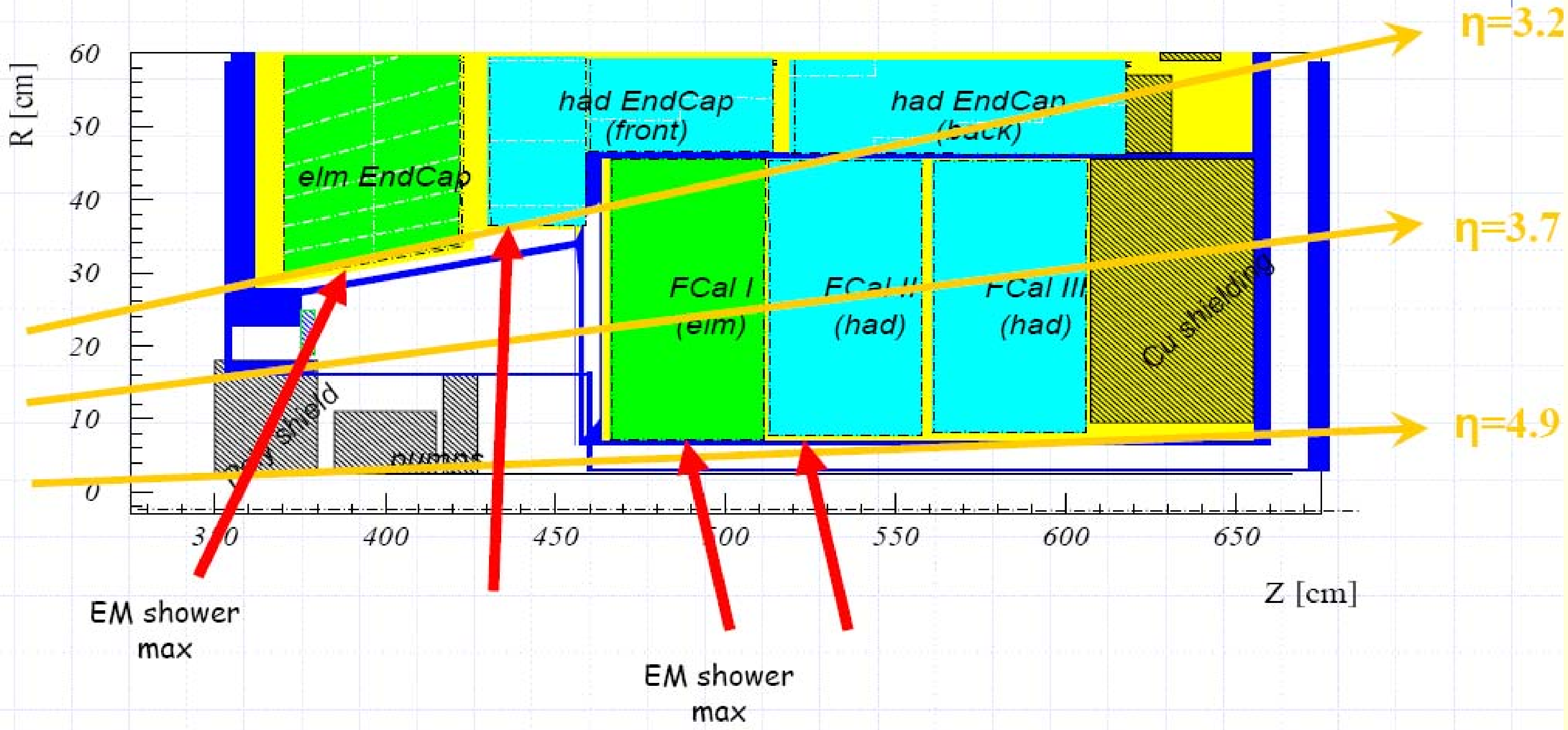
Depends on lumi, not on integrated lumi.

➔ Upgrade plans concentrating on the EndCap calorimeters.

Upgrade Plans for ATLAS calorimeters

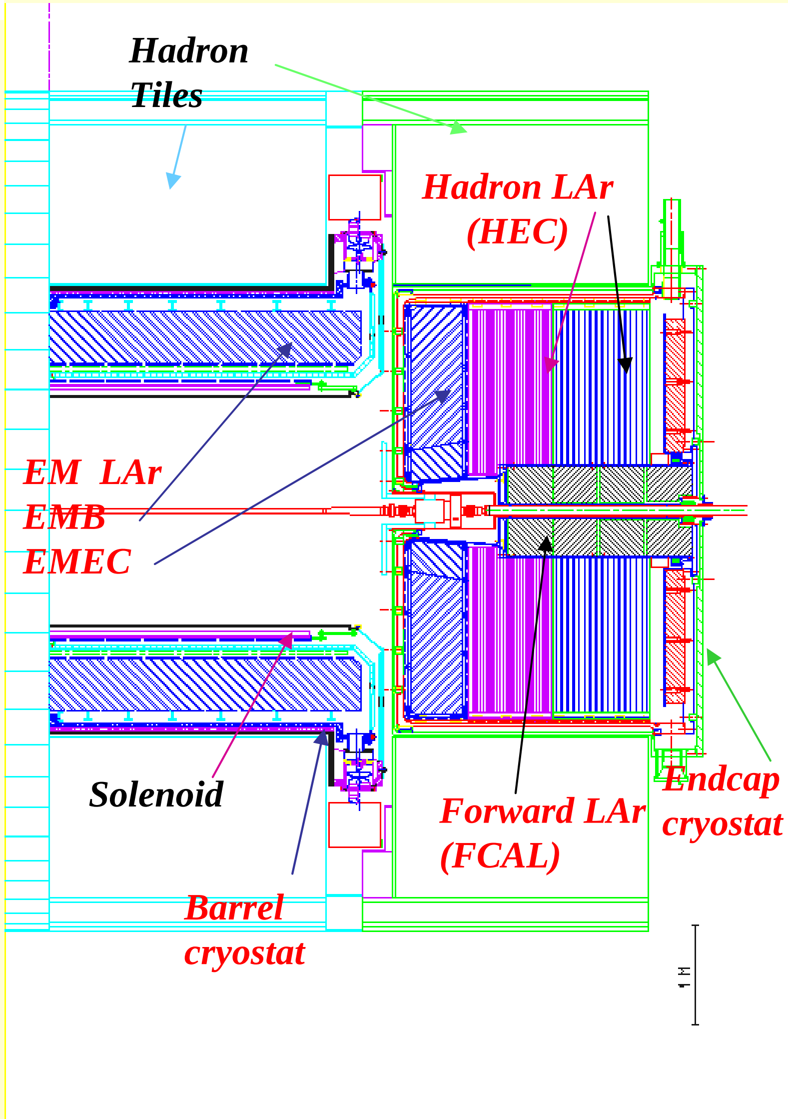
Worst location in modules

(Power density is largest)



4 December 2006 J. Rutherfoord 6

Upgrade Plans for ATLAS Calorimeters

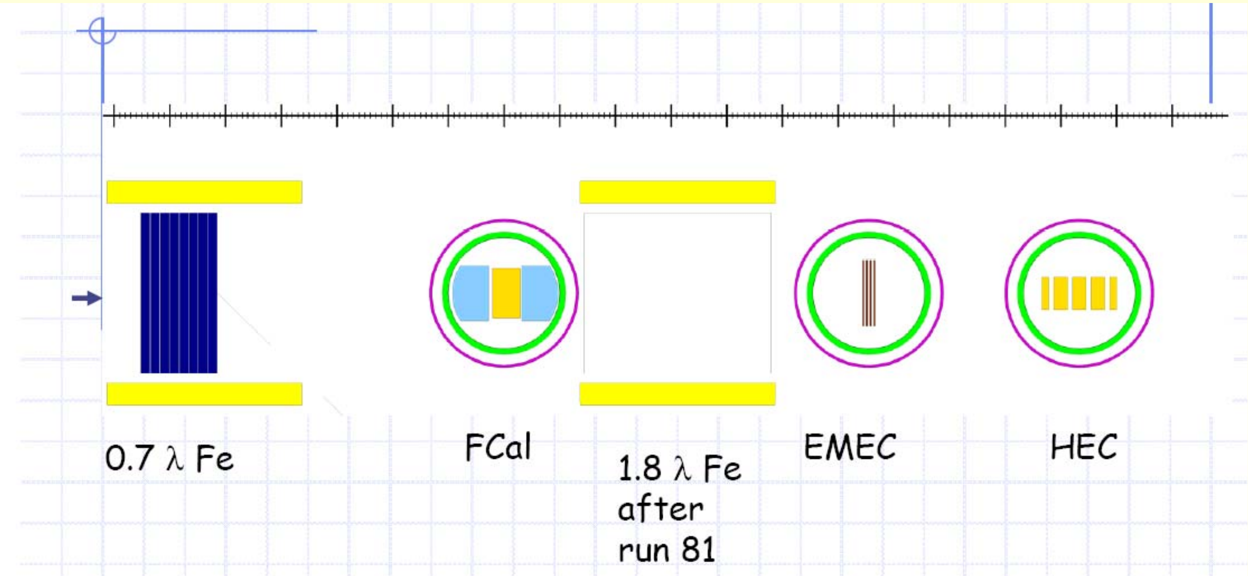


Separate points for the upgrade:

- **FCAL HV distribution system: current drawn at high lumi is large → voltage drop across the protection resistor too large.**
- **Space charge limited Operation: above critical rate signal is very sensitive to instantaneous lumi. Gain is therefore uncertain and fluctuating. Worst at EM shower max at highest η.**
- **Heat in FCAL, EMEC and HEC: heating due to dE/dx and due to ohmic heating → cooling in FCAL, maybe different electronics in HEC (not easy accessible)**

Upgrade Plans for ATLAS calorimeters

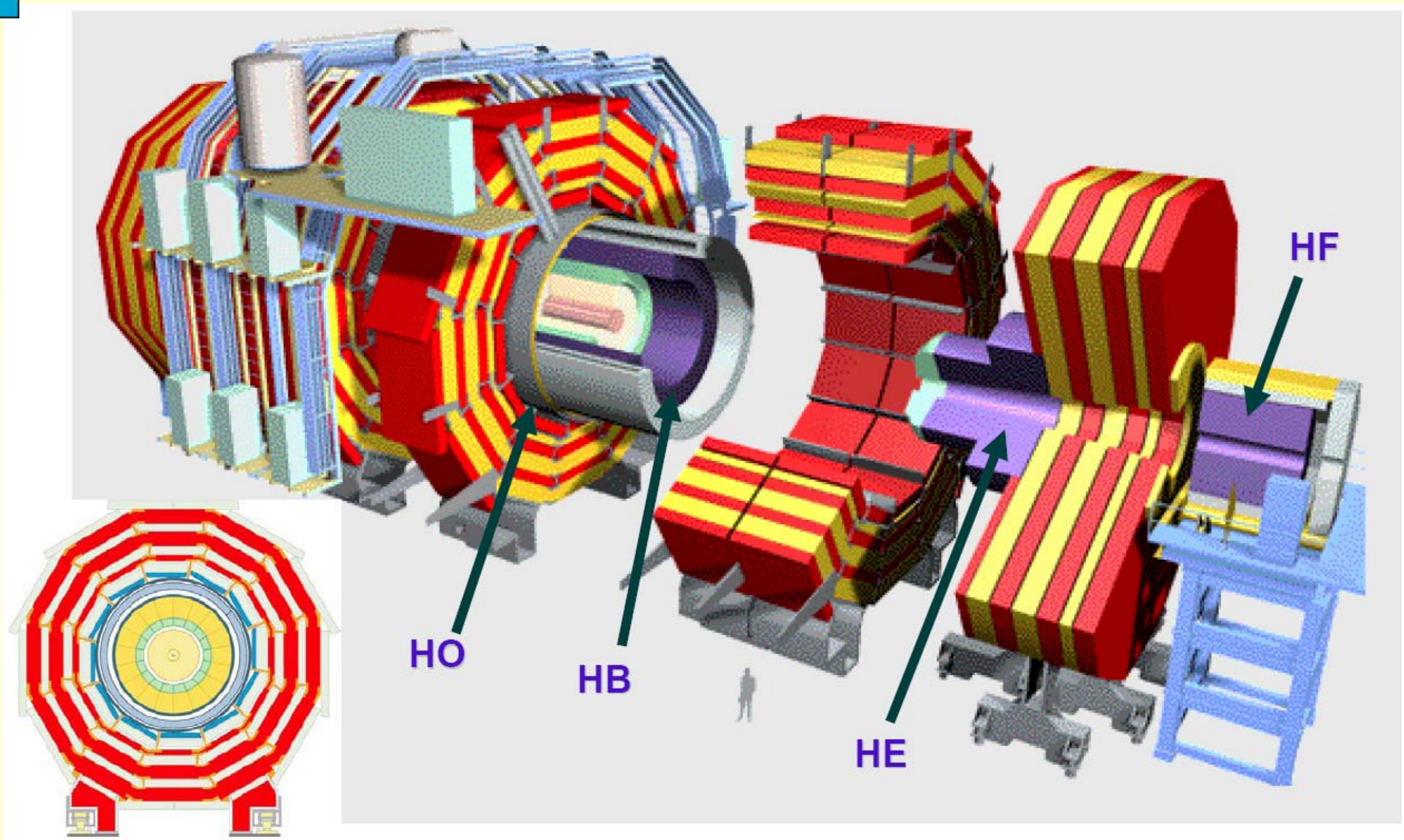
Measurements with high particle density beams under way:



Proposal draft in progress for FCAL (similar to present version):

- **Smaller LAr gaps, maybe as small as 100 µm in FCAL1**
- **Cooling loops to cool away the heating from dE/dx**
- **Modified HV distribution to reduce the voltage drop**
- **Minor changes from the experience with the present design.**

Upgrade plans for CMS



ECAL: minor worries about the performance of the ECAL endcap
→ studies just began

HCAL: in the process of defining several upgrade steps for the different HCAL parts.

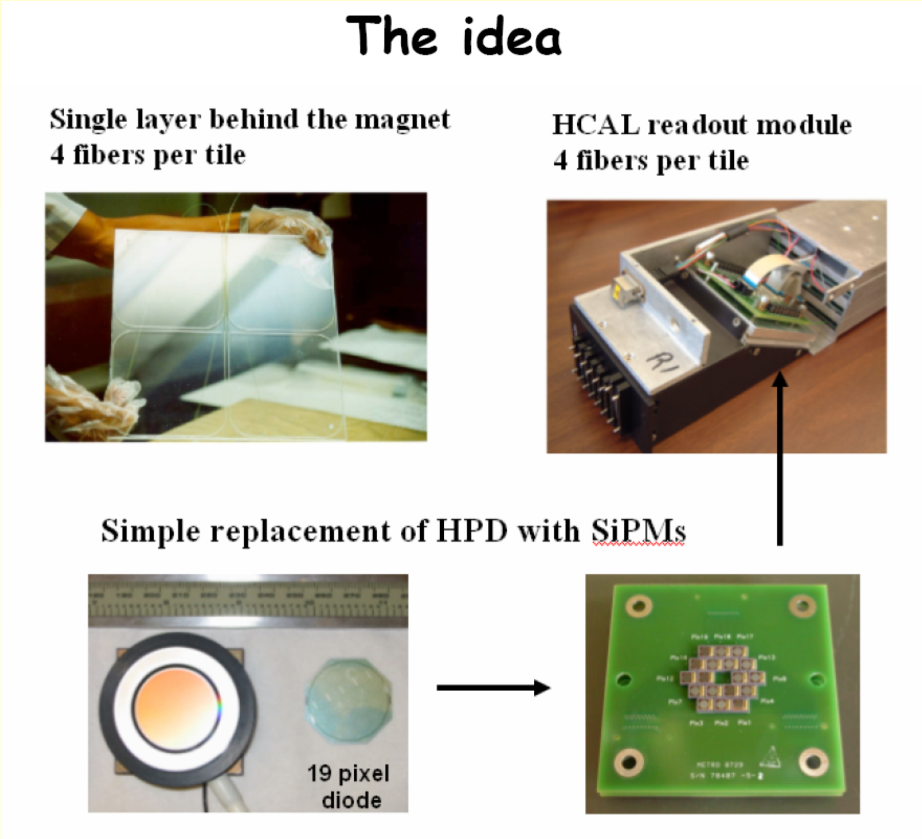
Upgrade Plans for CMS

Beginning of 2009 (?)

- **Replace HPD's with SiPM in HO**

Phase I: Lumi ~ 2E34 (2012-2013?)

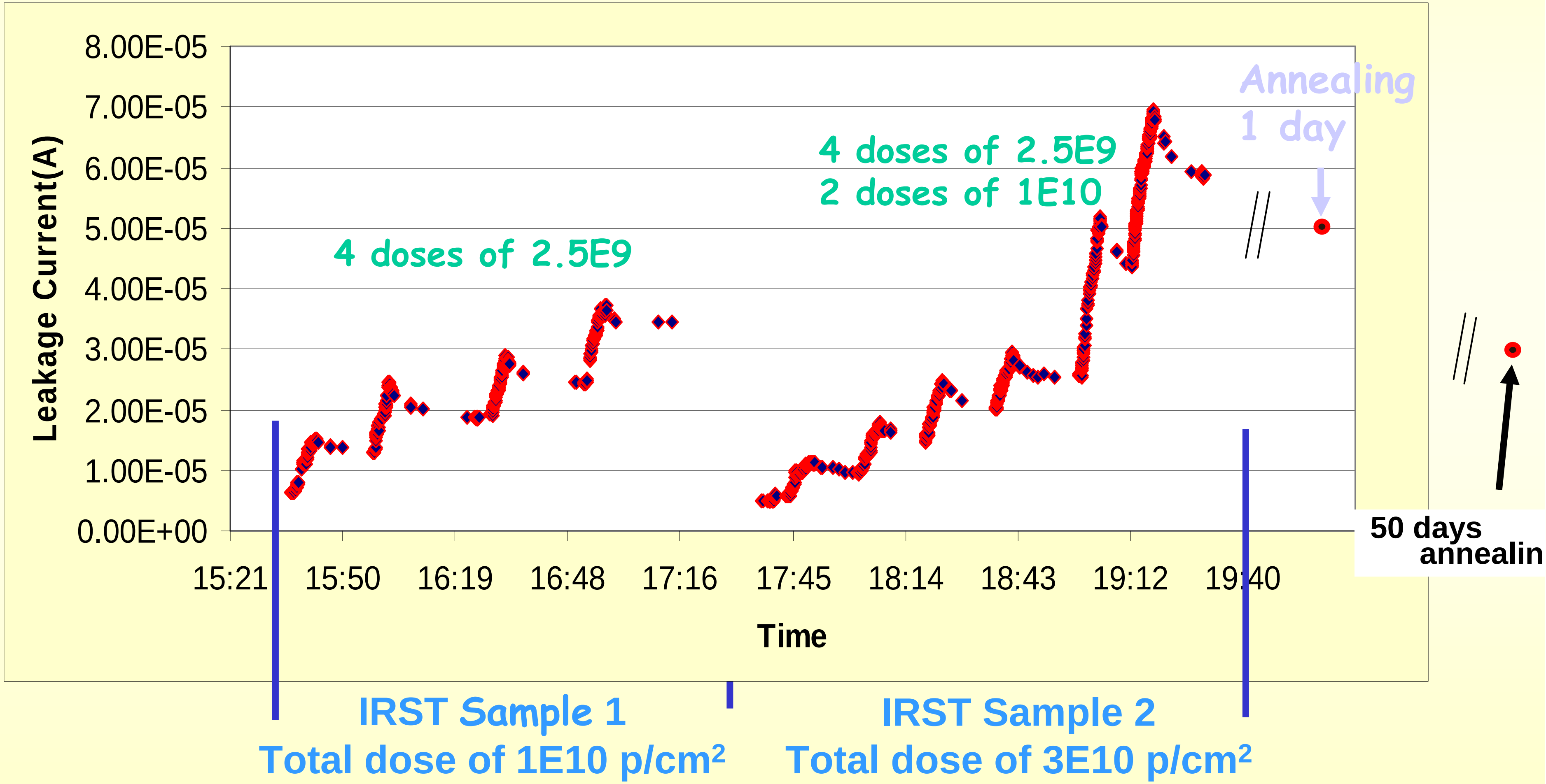
- **Replace all HPD's with SiPM**



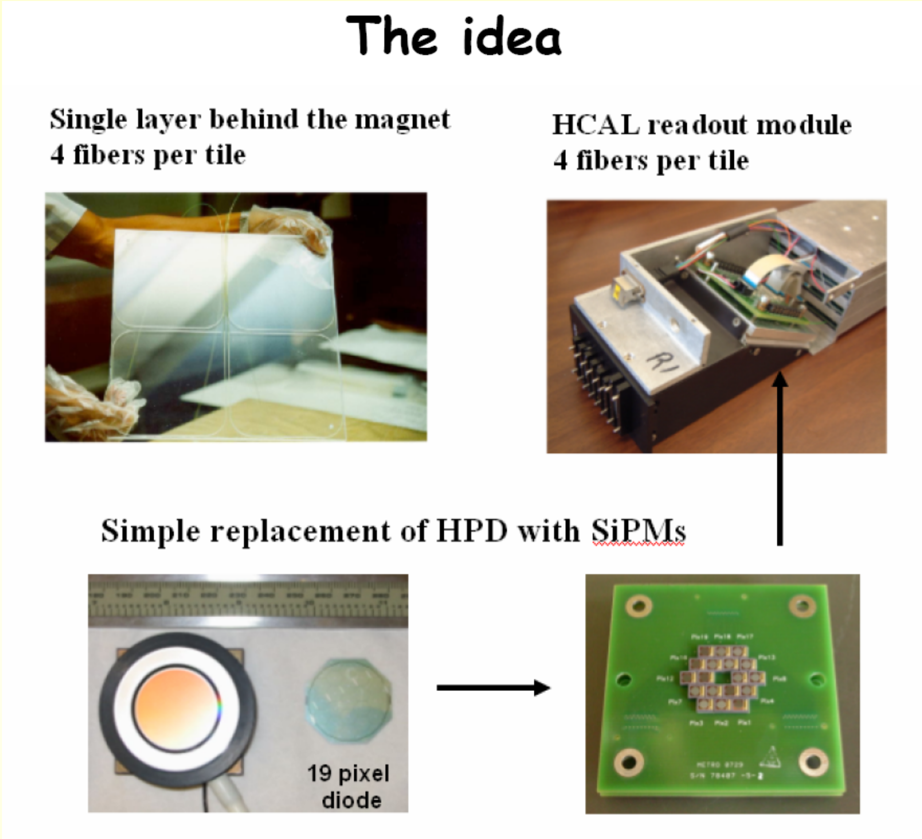
Upgrade Plans for CMS: SiPM

SiPM issues: radiation hardness and linearity

(see also ILC Detector developments)



Upgrade Plans for CMS



Beginning of 2009 (?)

- **Replace HPD's with SiPM in HO**

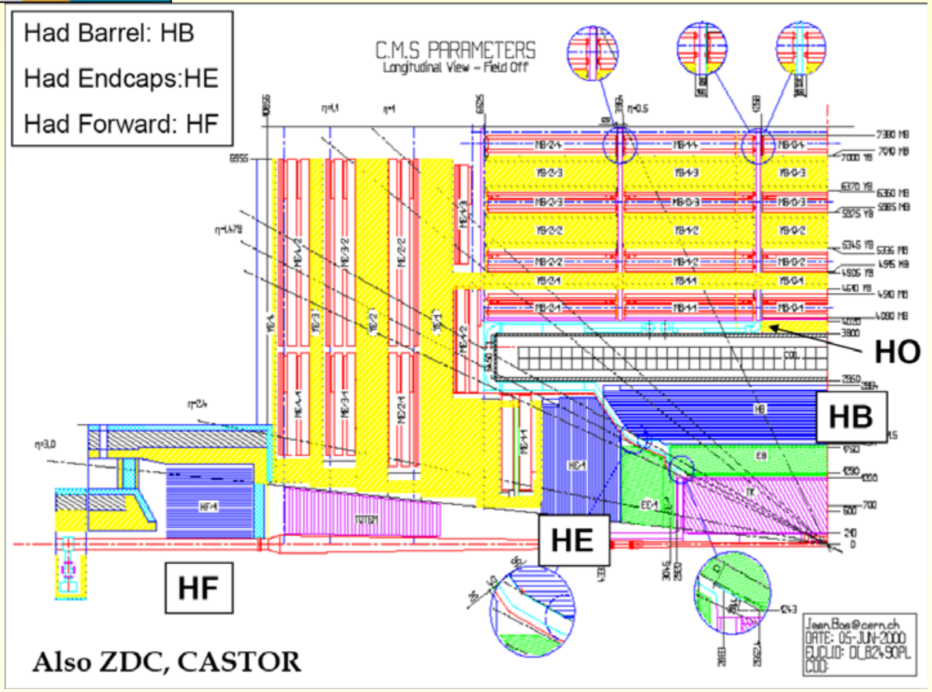
Phase I: Lumi ~ 2E34 (2012-2013?)

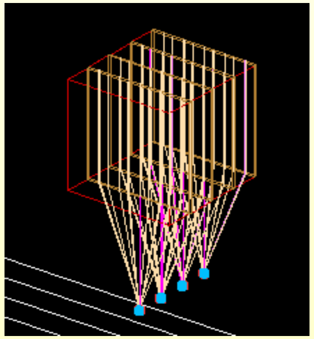
- **Replace all HPD's with SiPM**
- **Change longitudinal segmentation**
- **changes in the readout electronics , esp. in the trigger**
- **Rad-hard fibers in HF & high η**

Phase II: Lumi ~1E35(2017?)

- **Replace HE high η with Quartz-plates or Thick GEM**
- **HF very active, maybe complete replacement**

Upgrade Plans for CMS: HF

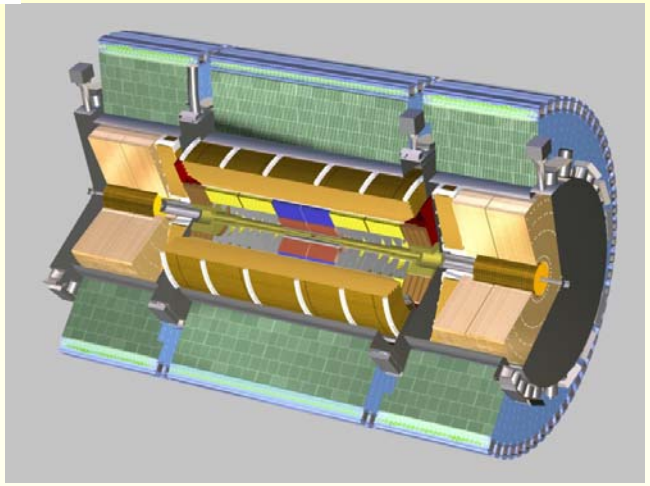


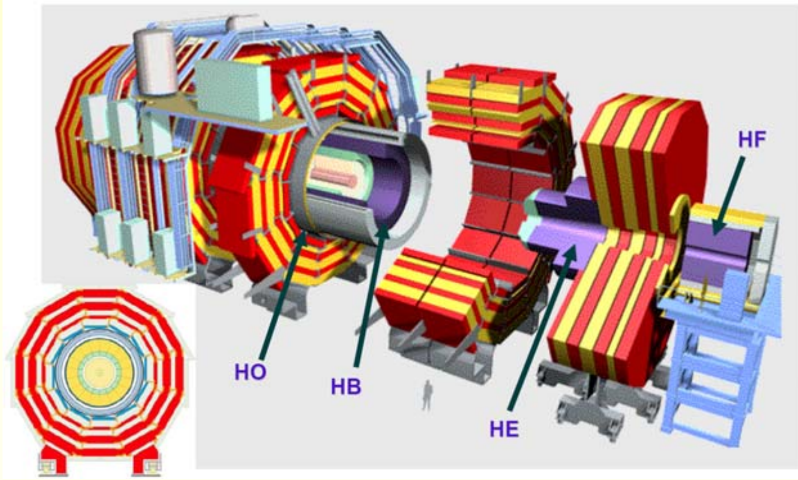


Different options under study:

- **Quartz plates**
- **Liquid/Gas Cherenkov radiators Liquid Scinitillators**
- **Gas Ionization (PPAC)**
- **Rad-hard detectors (as for ILC Forward Calorimetry**
- **CVD diamonds**

Summary





Calorimeters are pretty stable detectors → upgrade efforts started late

Barrel regions may not need any upgrade (beside electronics, if sLHC bunch crossing frequency changes)

Forward regions have largest burden in particle flow
→ heating, radiation, activation

→ most proposals concentrate on the forward region..

Thanks to Christian Zeitnitz (ATLAS), Drew Baden & Jim Freeman (CMS) for providing very helpful information ☺