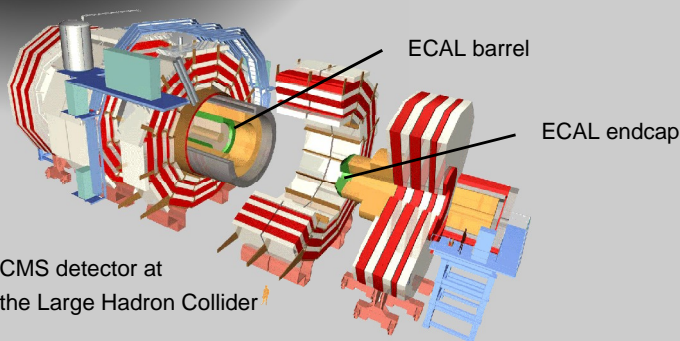




# Avalanche Photodiodes & Vacuum Phototriodes

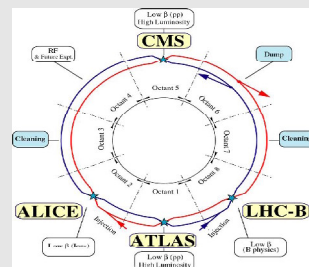
for measurement of scintillation light in the CMS Electromagnetic Calorimeter



CMS detector at the Large Hadron Collider

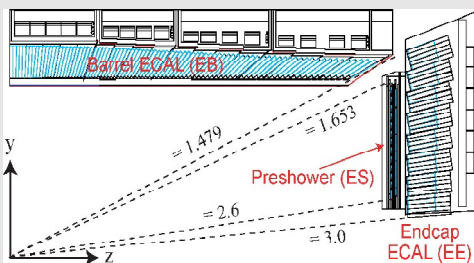
## The LHC at CERN

- 14 TeV proton-proton collider
- Bunch crossing rate 40 MHz
- First beams in 2007



## The CMS Electromagnetic Calorimeter

- 75848 lead tungstate crystals (61200 in barrel, 14648 in endcaps)
- Quasi-pointing geometry
- Inside 4T axial magnetic field of CMS
- Harsh radiation environment
  - γ dose up to 50 kGy
  - up to  $2 \times 10^{14}$  neutrons/cm<sup>2</sup>



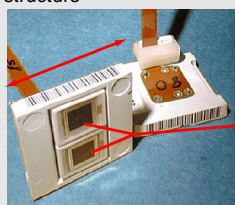
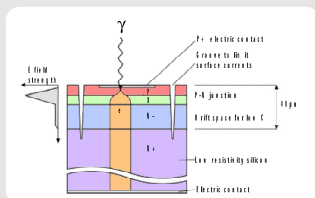
## Optical sensor requirements

- Good response at 400-450 nm
- Fast response - less than 25ns
- Radiation-hard for 10 years LHC running
- Operate in 4T magnetic field
- Cost-effective

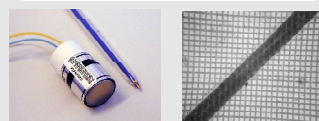
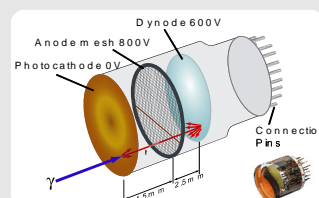
## APDs

### Avalanche PhotoDiodes

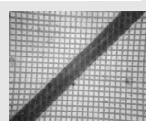
- Radiation-hard for barrel, but not suitable for higher dose rates in the endcaps.
- Hamamatsu type S8148 reverse structure
- Active area 5x5 sq mm
- 2 APDs per crystal
- Mean gain of each pair = 50
- QE typically 75%



Two 5x5mm APDs are mounted in a plastic assembly before gluing onto the crystal.

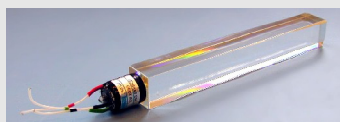


Connection pins encapsulated to prevent high voltage tracking



Close-up of the anode mesh, with human hair for comparison.

VPT mounted on a Lead Tungstate (PbWO<sub>4</sub>) crystal



## VPTs

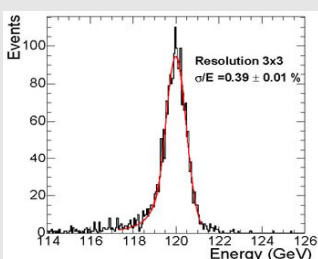
### Vacuum PhotoTriodes

- Radiation-hard at highest endcap doses
- Single-stage PMT
- RIE PMT188
- Active area 380 sq mm
- Typical gain 10
- Typical QE 20%
- Mesh anode, pitch of 10μm

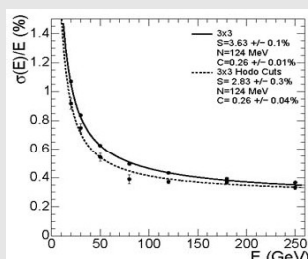
## Test Beam results

- ECAL energy resolution driven by Higgs → γγ
- Need resolution of 0.5% at 100GeV to resolve signal above expected background

Distribution of the energy reconstructed in a 3x3 cluster of crystals, for electrons incident in a 4x4 sq mm region at the centre of the cluster



Measured ECAL barrel energy resolution as a function of electron energy. The upper points (solid line) correspond to electrons incident in a 20x20 sq mm region, the lower points (dotted line) to a 4x4 sq mm region.



## Comparison

Characteristic	APD	VPT
Gain	50	10
Quantum Efficiency	80% at 430nm	20% at 420nm
Speed	25ns	25ns
Temperature dependence	-2.4% / °C	
Radiation Hardness	Good	Very good
Operate in 4T magnetic field?	Transverse	Axial
Cost		US \$50
Operating voltage	400V	800V
Typical Dark Current	3nA	1nA

contact:

laboratory

6216