India in CMS

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Panjab University Chandigarh, India

(On Behalf of the India-CMS Collaboration)

DST Linear Collider Meeting Nov 10-11, 2003

Overview of Talk

- LHC Programme at CERN
- CMS Experiment
- CMS Physics Aims
- Indian Paticipation in CMS
  - ✓Hardware
  - ✓Software
  - ✓Physics Simulation
- Funding Issues

LHC Programme

LHC Programme at CERN

- **The next CERN flagship Research Program is Based upon Large Hadron Collider (LHC)**

- **Year 2007: 7TeV + 7TeV proton-proton(pp) collisions**
  - ✓ **Two large pp Experiments : ATLAS, CMS**
  - ✓ **Heavy Ion Experiment : ALICE**

- **Major PHYSICS aims for pp Experiments**:
  - ✓ **Investigate mechansim of mass generation in the Universe (Search for HIGGS particle)**
  - ✓ **SUSY Search**
  - ✓ **Search for other new particles ,Unknown Physics**

Indian Participation in CMS

- **Five Indian Groups in CMS**

  Panjab University, Chandigarh

  Delhi University, Delhi

  BARC, Mumbai

  TIFR(HECR), Mumbai

  TIFR(EHEP), Mumbai

  40 Scientists and Engineers

  6-7 Research Students.

- **Formed India-CMS Collaboration**

CMS Detector

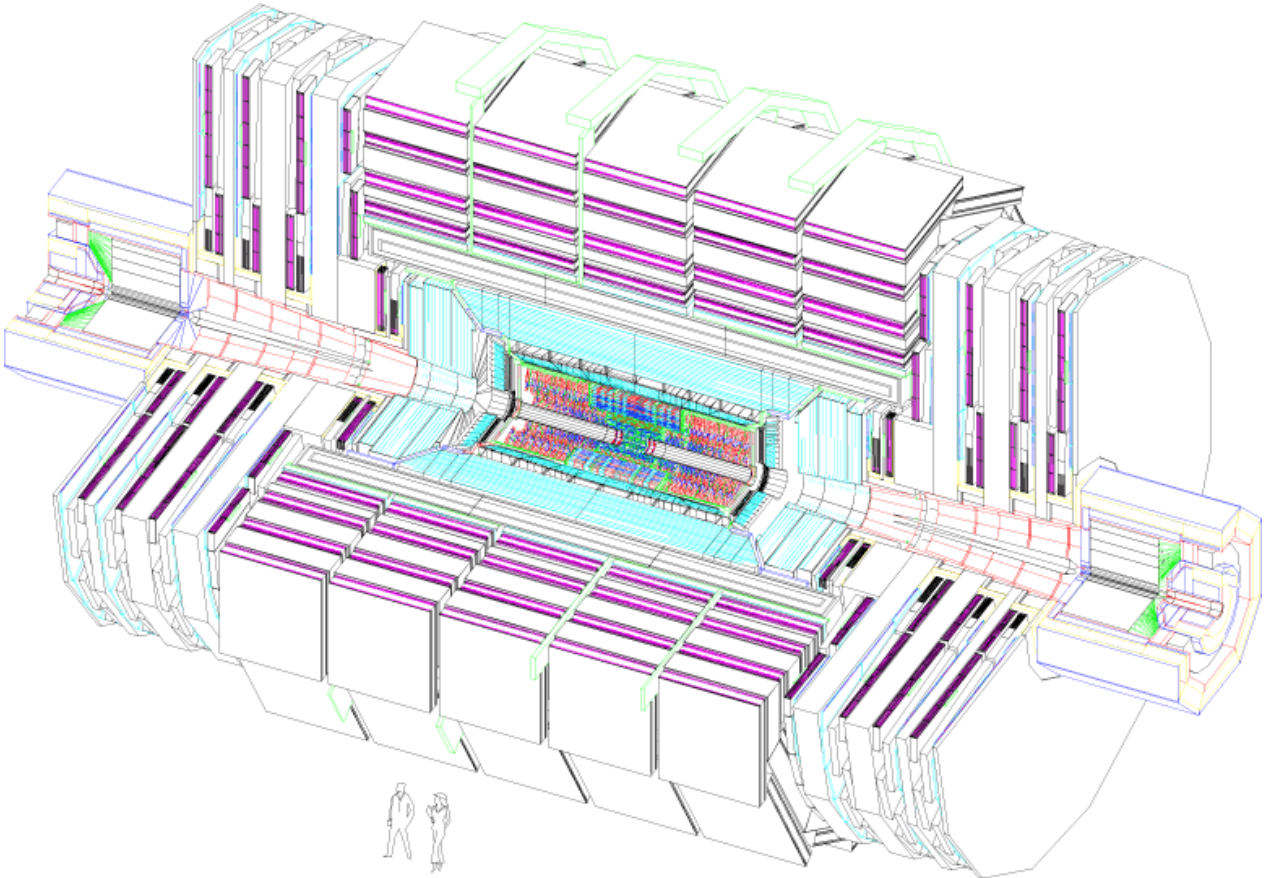
The CMS Detector is

- ✓ 22 meter Long, 14 meter dia., 12500 tons
- ✓ Central vertex detector and tracker for charged particle measurements
- ✓ High resolution crystal electromagnetic calorimeter for electron and photon measurement + F/B silicon PreShower Detector
- ✓ Hermetic Hadron Calorimeter
- ✓ 4 Tesla Superconducting Solenoidal magnet
- ✓ 4 Layers of Muon detectors

Detector Design well optimised for the Physics Needs

(Discovery of HIGGS, Search for NEW PHYSICS)

CMS Detector



Indian Hardware Activities

Hardware responsibility of India-CMS

- **Panjab University +TIFR: 3-groups**
  - Outer Hadron Calorimeter (HO)
  - HO improves hermeticity of energy measurement
  - CRUCIAL when looking for NEW PHYSICS
    e.g. SUPER-SYMMETRIC PARTICLES

- **BARC + Delhi University:**
  - Silicon Preshower Detector (Si PSD)
  - BARC Also: Electronics for the Si PSD is being developed.
  - This detector enhances discrimination between photons & neutral pions in HIGGS Search

Outer Hadron Calorimeter

Outer Hadron Calorimeter HO-Indian

- ✓ **Location: Just inside 1st Muon Layer**
- ✓ **Material: 450 m^2 of 1 cm thick Plastic**
  - ✓ **Scintillator detector with embedded**
  - ✓ **wavelength shifting fibre(WLS)**
- ✓ **Readout: light transmission via clear optical fibers to HPD detector**
- ✓ **Unit Detector is a Tray ⇨2.51 m long & ~35 cm wide**
- ✓ **Each TRAY consists of scintillator tiles.**

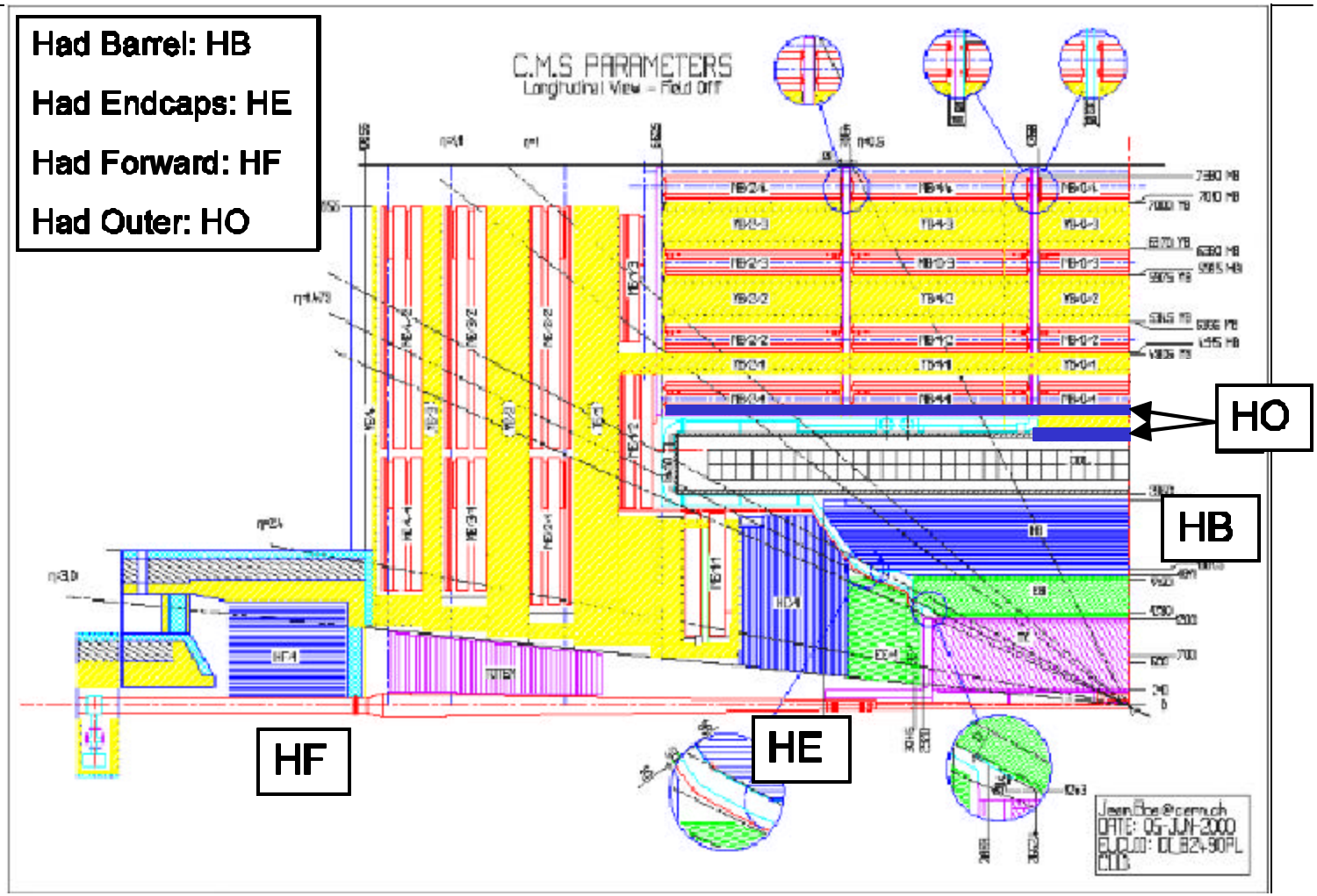
Hadronic Calorimeter: HCAL

Had Barrel: HB

Had Endcaps: HE

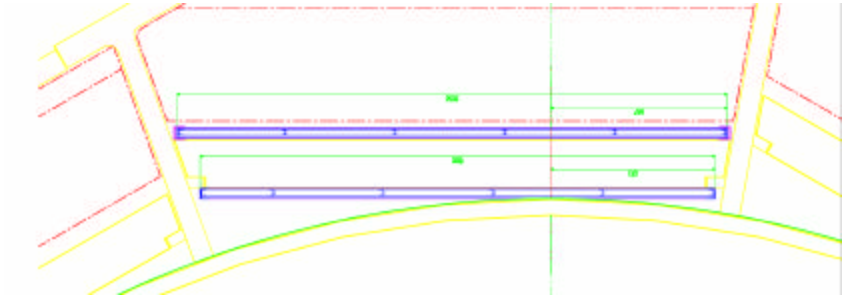
Had Forward: HF

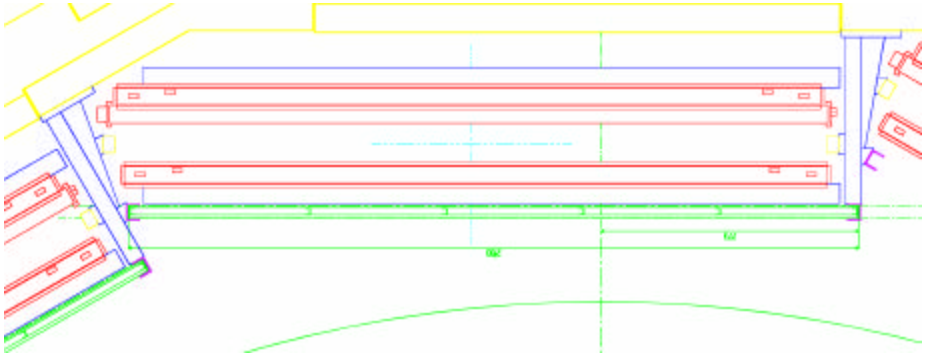
Had Outer: HO



HO Coverage

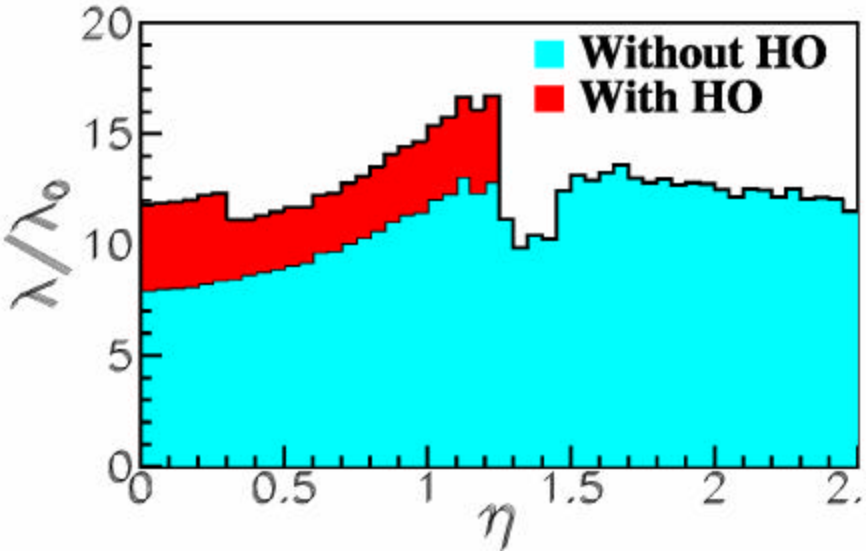
- → HO covers the central rapidity region (|h| < 1.26) occupied by the five Muon Rings. (numbered as -2,-1,0,1,2)
- → For Ring 0, there will be two HO layers (Layer 0 & 1) on either side of the 18 cm thick tail catcher iron at R=3.82 m and 4.07 m
- → For Rings -2,-1,1 & 2, there will be a single HO layer (Layer 1) at R= 4.07 m





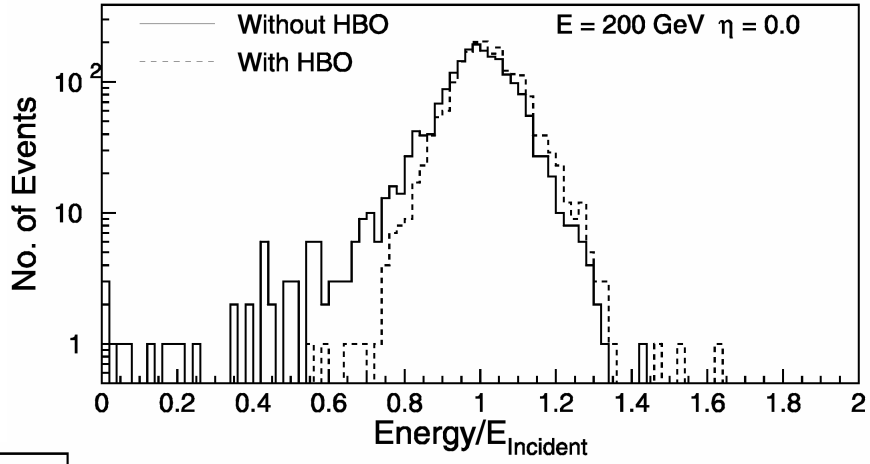
Need for HO

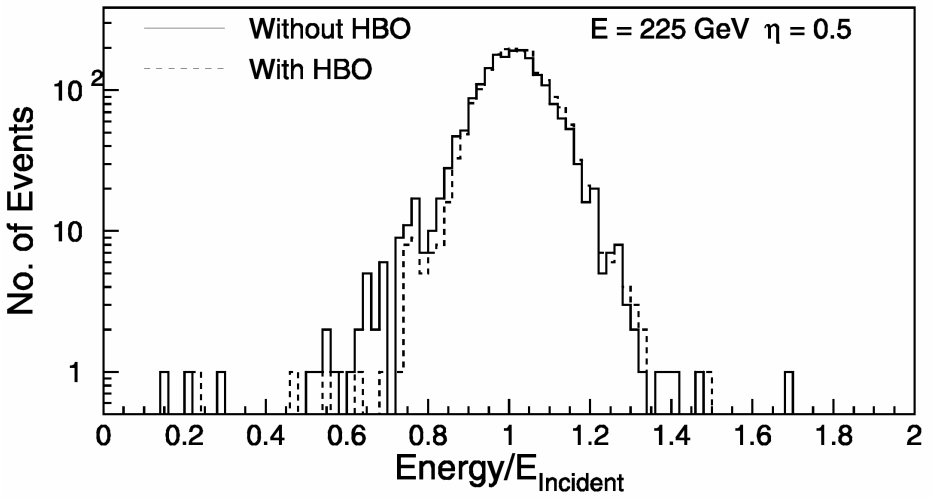
- In the central region, HB is not thick enough to contain hadronic shower fully, particularly those fluctuated showers which develop deep inside the HCAL.
- Need to extend HCAL outside the solenoid magnet and make additional sampling of the shower.
- This part outside the magnet coil is referred as Outer Hadron Calorimeter (HO)



Simulation Study-HO

Effect of leakage is visible from 70 GeV and increases with energy



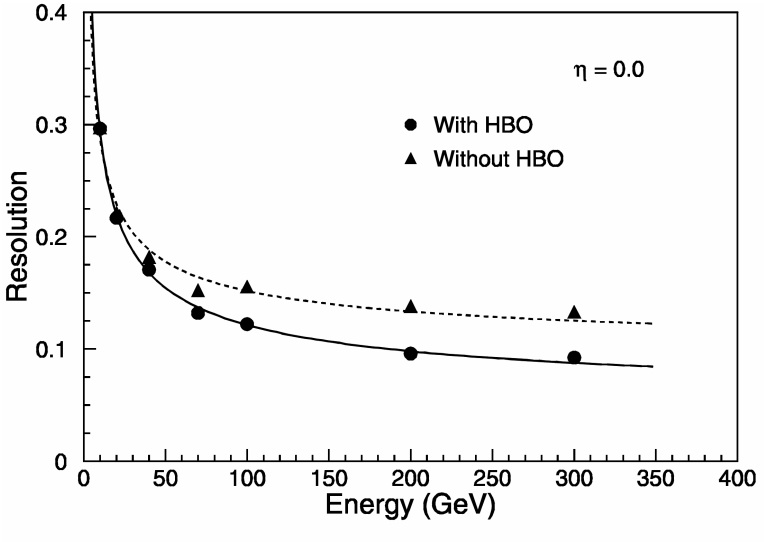


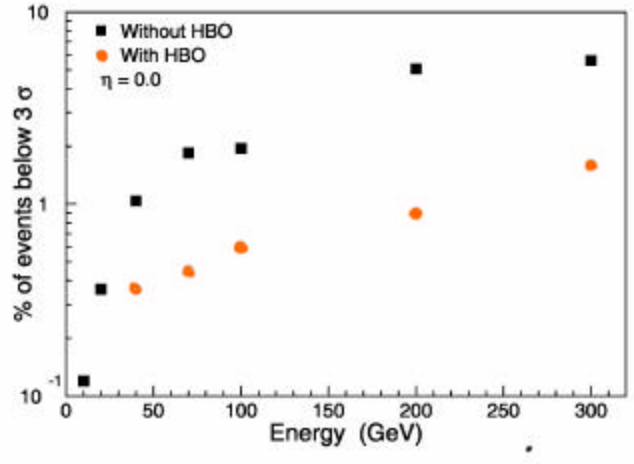
Effect of leakage is smaller at higher h

Simulation Study-HO

Energy resolution:

The constant term improves after addition of HO



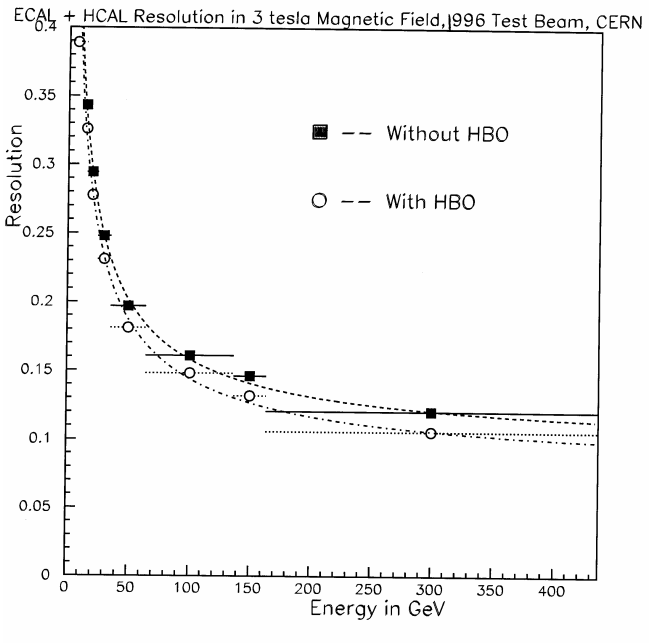


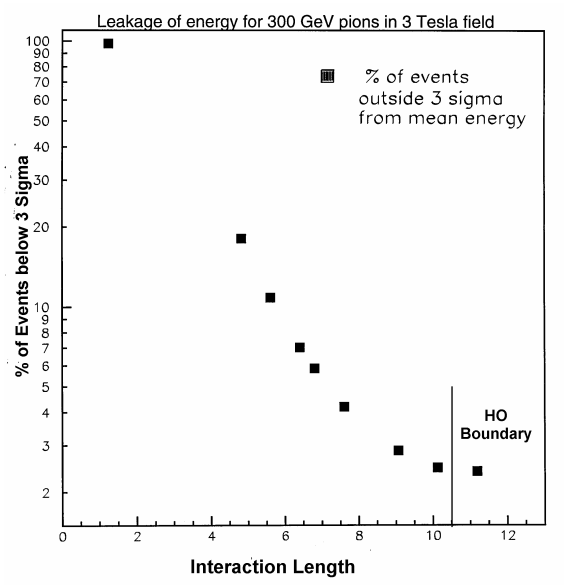
Fraction of events having measured energies 3s below the mean value

Leakage is < 1%

1996 Test beam results

Energy Resolution





Leakage

Design Consideration

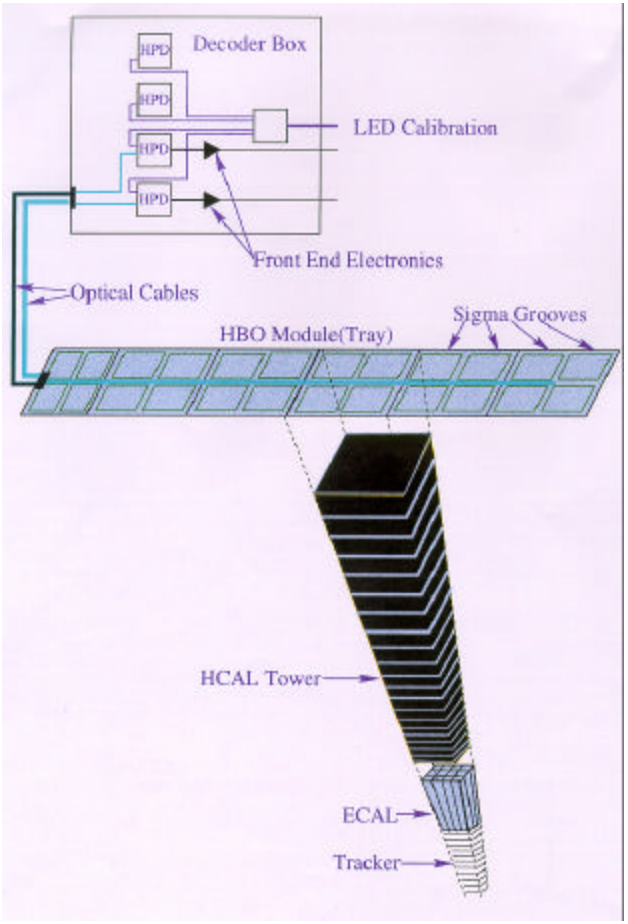
✓**Basic Detector Elements should map the barrel hadron Calorimeter (HB) towers of granularity 0.087 X 0.087 in** h **and** f.

✓ **Should be able to see MIPS.**

⇓

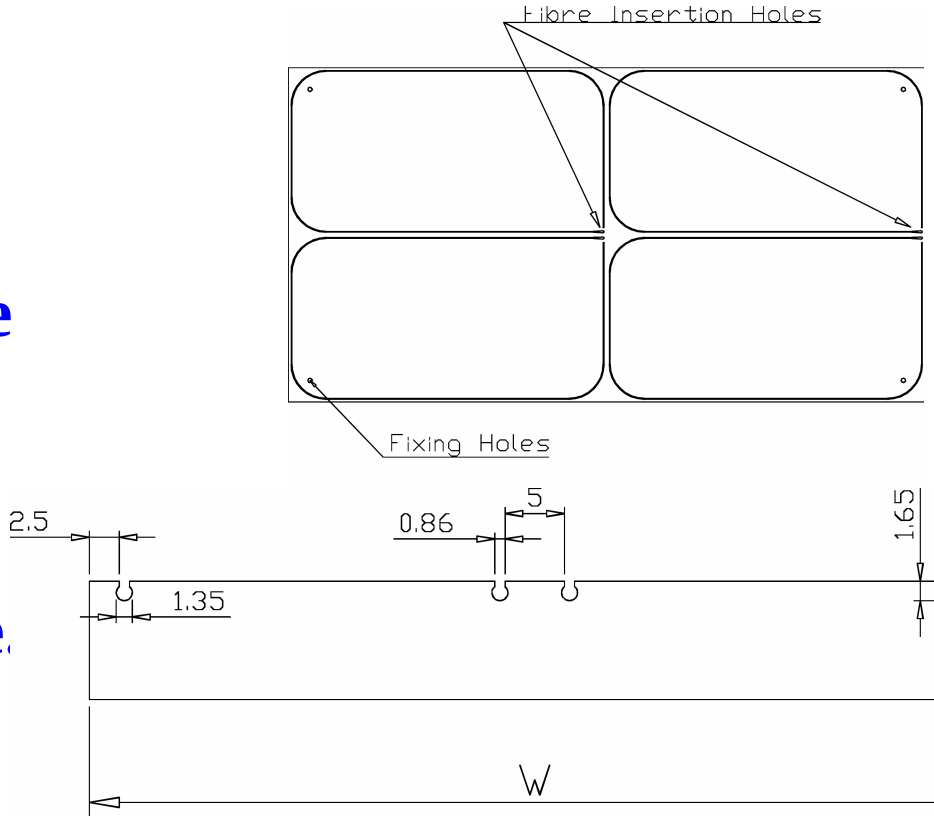
✓**10 mm thick Bicron BC408 scintillator to be used as the active element.**

✓**Use 0.94 mm dia WLS Kuraray double clad fibers (in** s **shapped grooves), spliced to clear fibers to carry light to HPDs located on the outer edge of the muon system.**



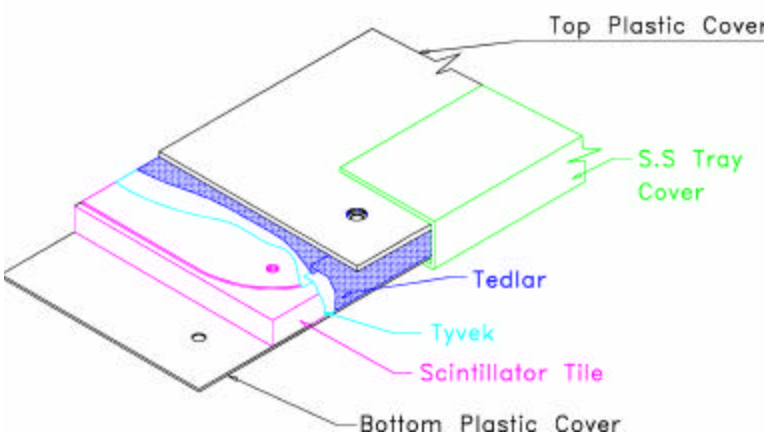
HO Tile design

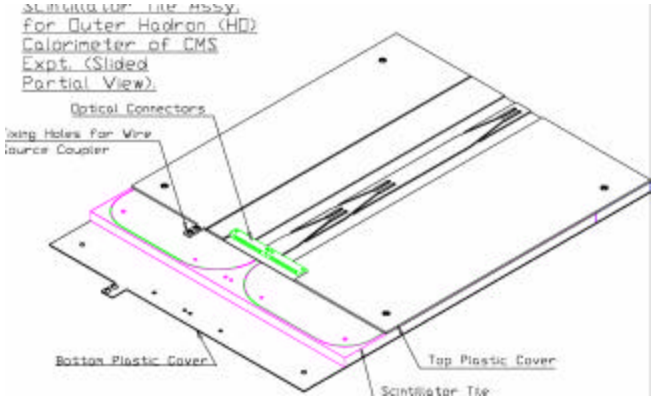
- Light from individual tile is collected using WLS fiber.
- Fibers are held inside the tile in keyhole type grooves
- There will be 4 identical s shaped grooves per tile.
- HO has 95 different tile dimensions, 75 for layer 1 and 20 for layer 0.



HO Tray Assembly

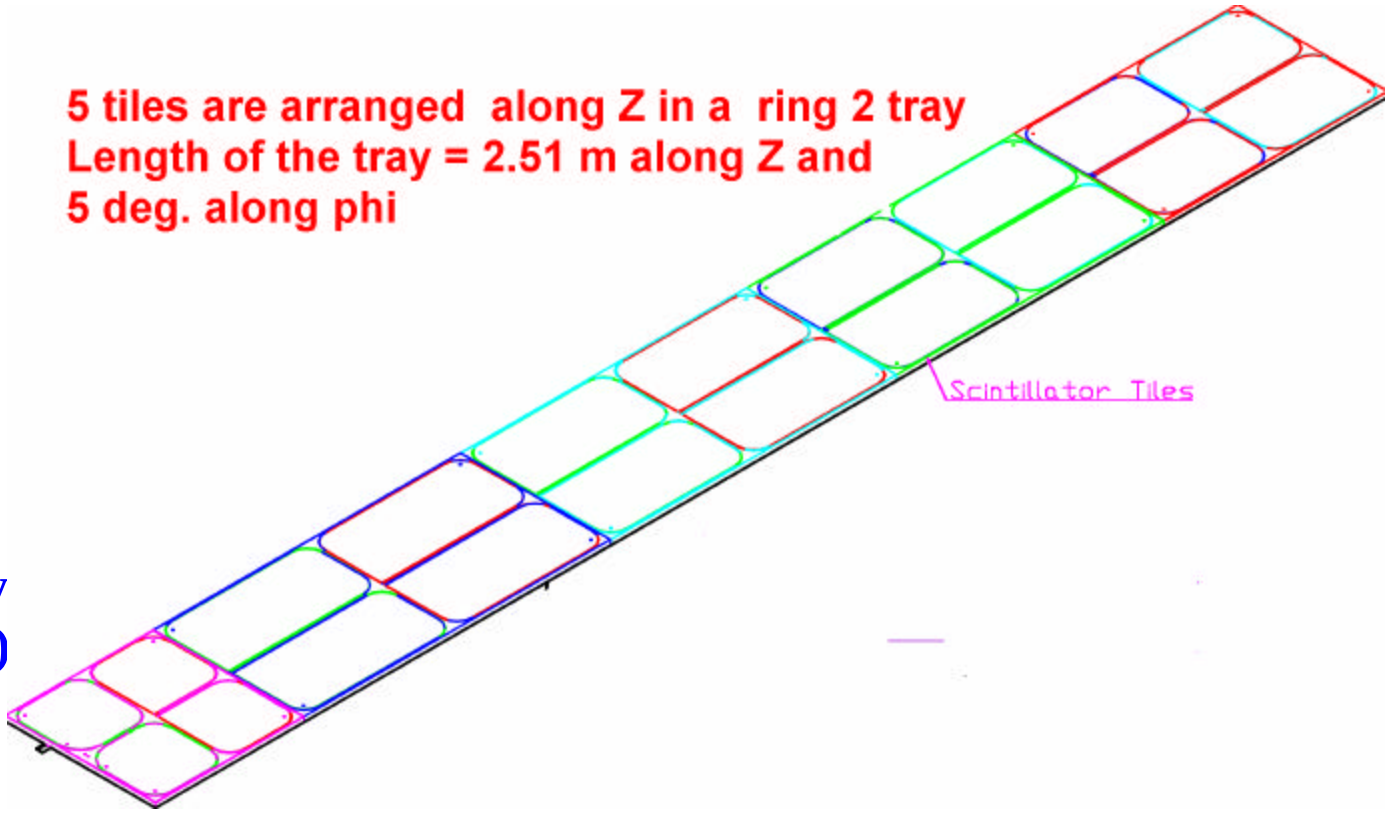
- Tiles in a tray are covered with tyvek and tedler.
- Tiles are sandwiched between two plastic plates of 2mm and 1mm thickness for mechanical stability and ease of handling.
- 2mm thick plastic cover have grooves to route the fibers from tiles to edge connector.
- Additional groove for the source tube





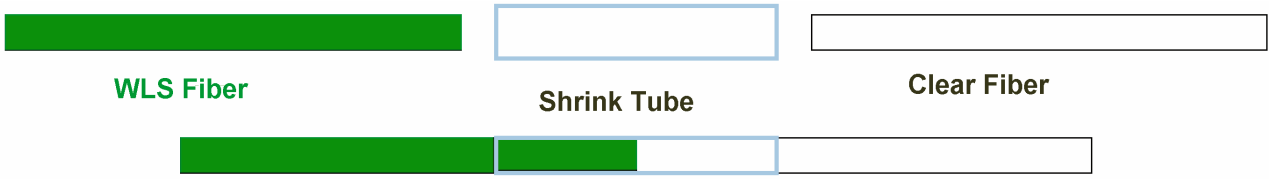
HO Tray Design

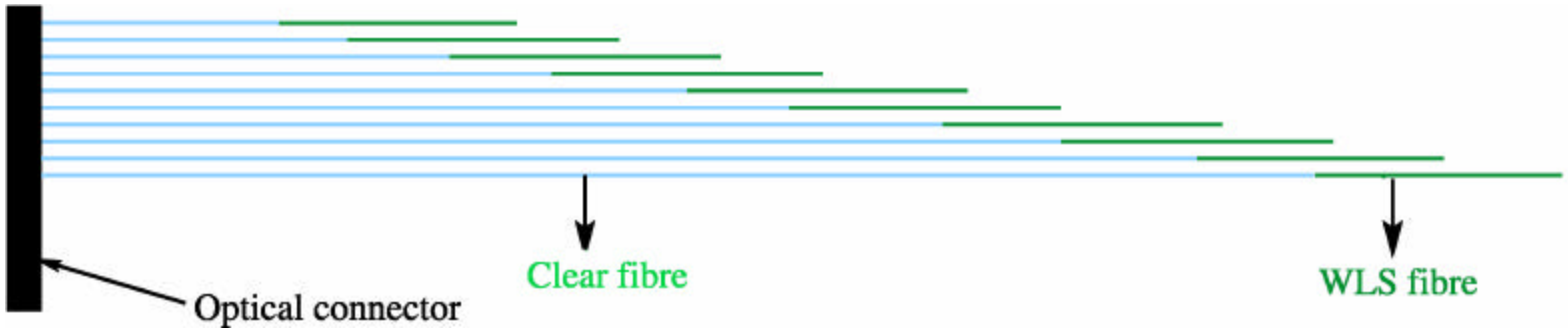
- All the tiles in the same ϕ slice of a ring will be packed as a single mechanical unit called the "tray".
- It will cover the entire length of a muon ring along Z.
- Along η, it will only be one tile wide (5^0)



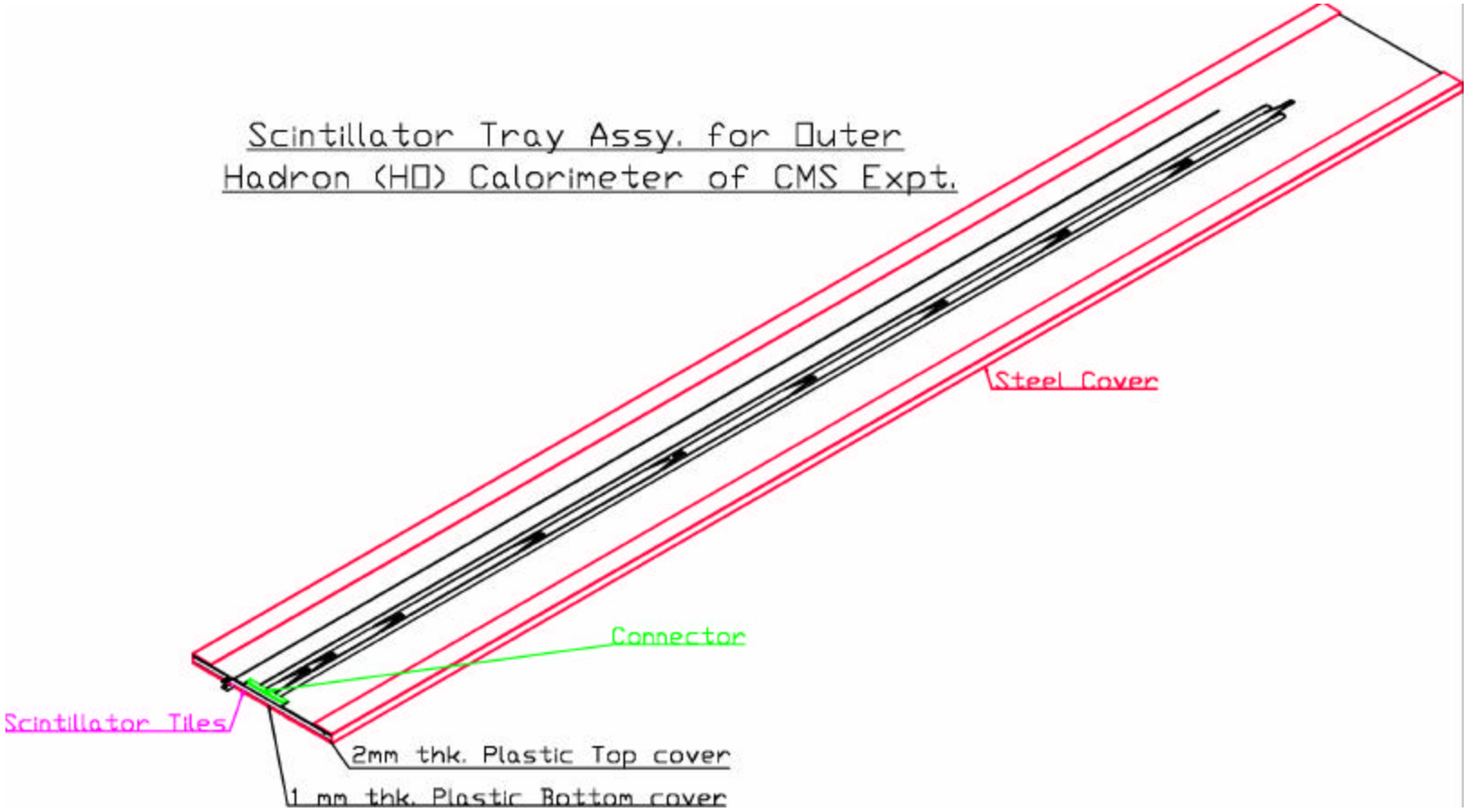
Light collection

- **Clear fibers spliced to WLS fiber will transport scintillation light to an optical connector located at the edge of the tray.**

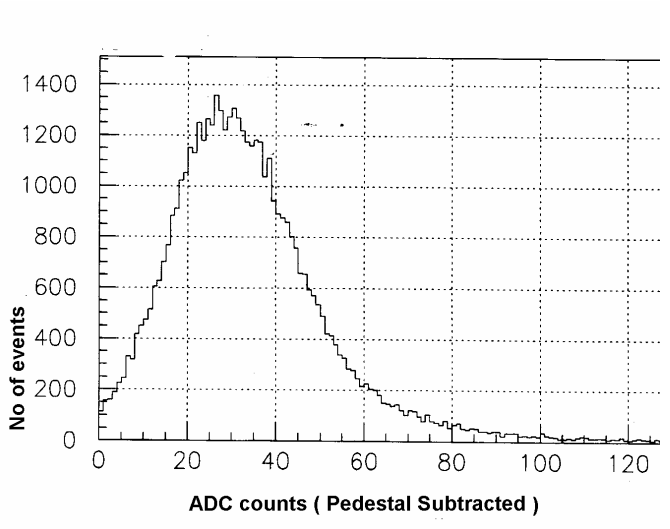


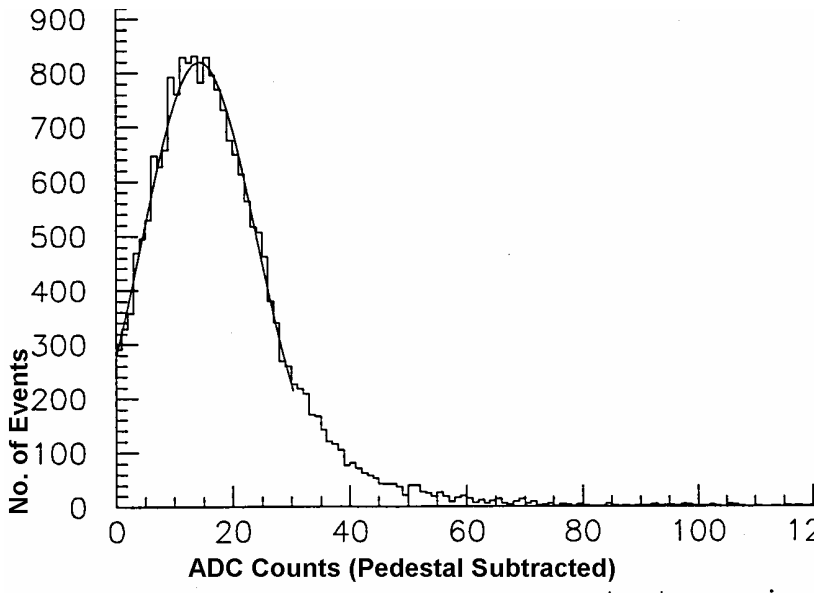


Full Tray


Scintillator Tray Assy. for Outer
Hadron (HO) Calorimeter of CMS Expt.
Steel Cover
Connector
Scintillator Tiles
2mm thk. Plastic Top cover
1 mm thk. Plastic Bottom cover

Test Beam Results





- **Pedestal subtracted muon ADC signal from a ring 0 HO tower- (layer 0 and layer 1 combined)**

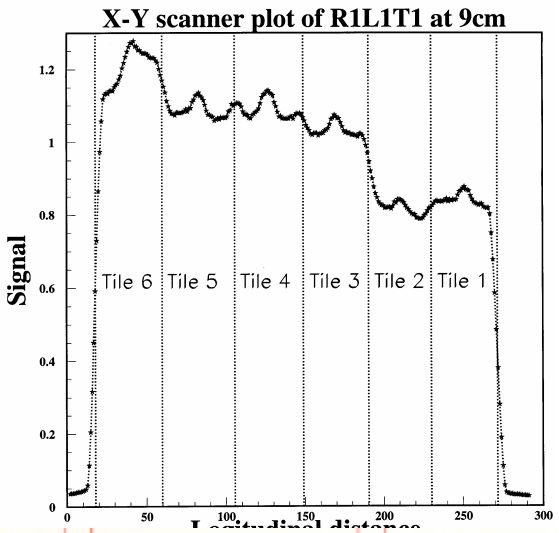
  Signal = 34.7, s_p= 9.4, S/N = 4

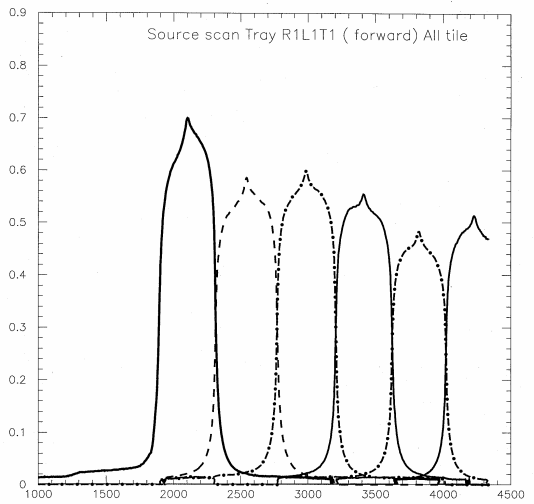
- **Pedestal subtracted muon ADC signal from a ring 1 tile (Single layer).**

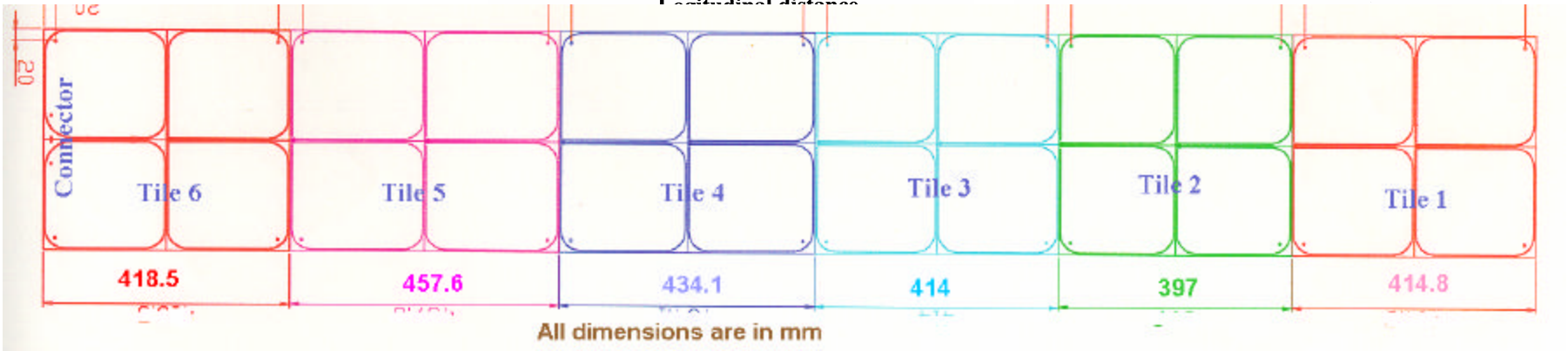
  Signal = 18, s_p=10, S/N = 1.8

Source Calibration

HO trays have also been calibrated using wire source scanner as well as X-Y source scanner







List of HO items

- **Number of Tiles : 2736**
- **Number of Trays : 432**
- **Number of Pigtails : 864**
- **Number of optical cables : 864**
- **Area of scintillators : 380 Sq. mt.**
- **WLS fiber length : 12 Km**
- **Clear fiber length : 90 Km**

HO Milestones

Milestones

1999:Pre-Production prototypes sent to CERN & Beam-tested

2000:Engineering & Design Review Approved & Beam Tested

2002:Full Fabrication of Detectors started

2003:PRODUCTION COMPLETED & Already AT CERN

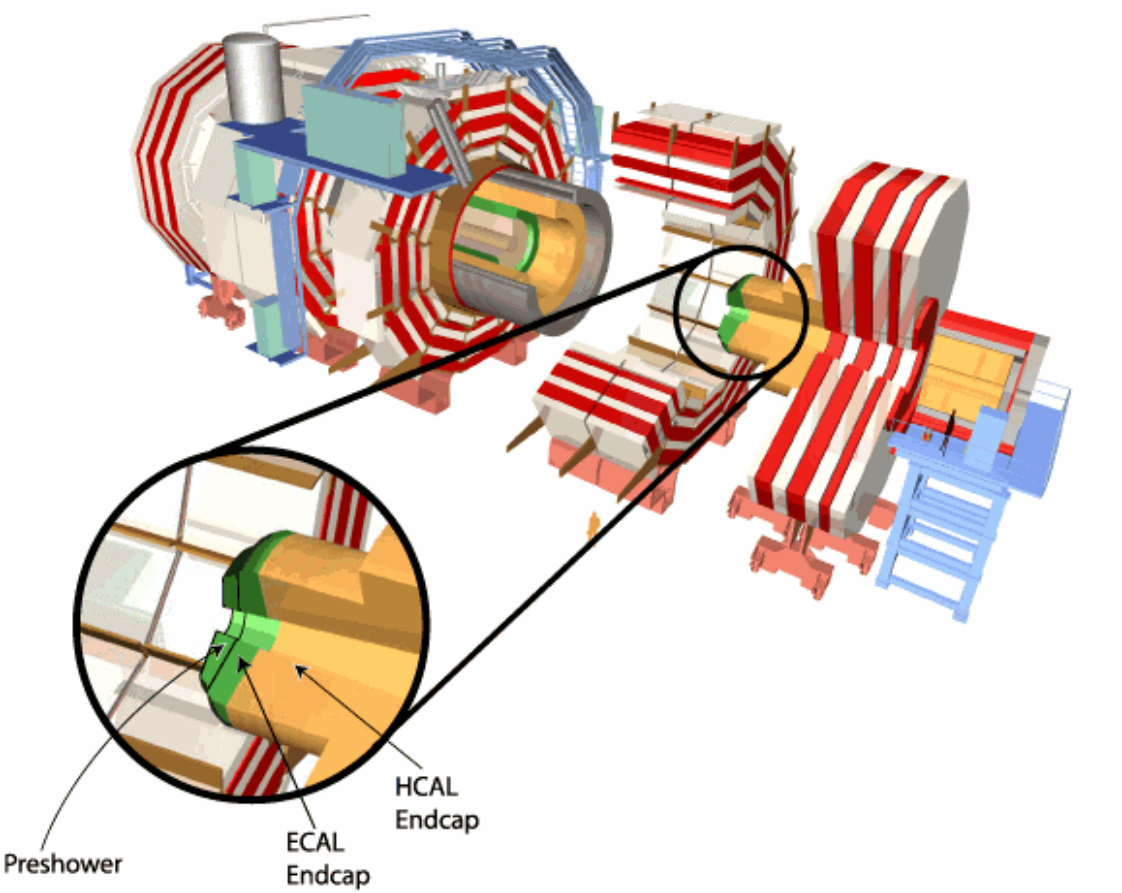
All Trays tested with Radio-active and Cosmic Rays

Again Retested Radioactive Source at CERN

Final Installation inside CMS detector:

March-April,2004

Si-PSD in CMS



CMS PreShower Detector

Silicon Preshower Detector (Si-PSD)

Total CMS Si-PSD Detector(Endcap) = 4300

India to Contribute (BARC+DELHI) = 1000

CEERI(Pillani) + BEL(Banglore)

R&D within India-CMS framework.

1st time Production of such Detectors in India.

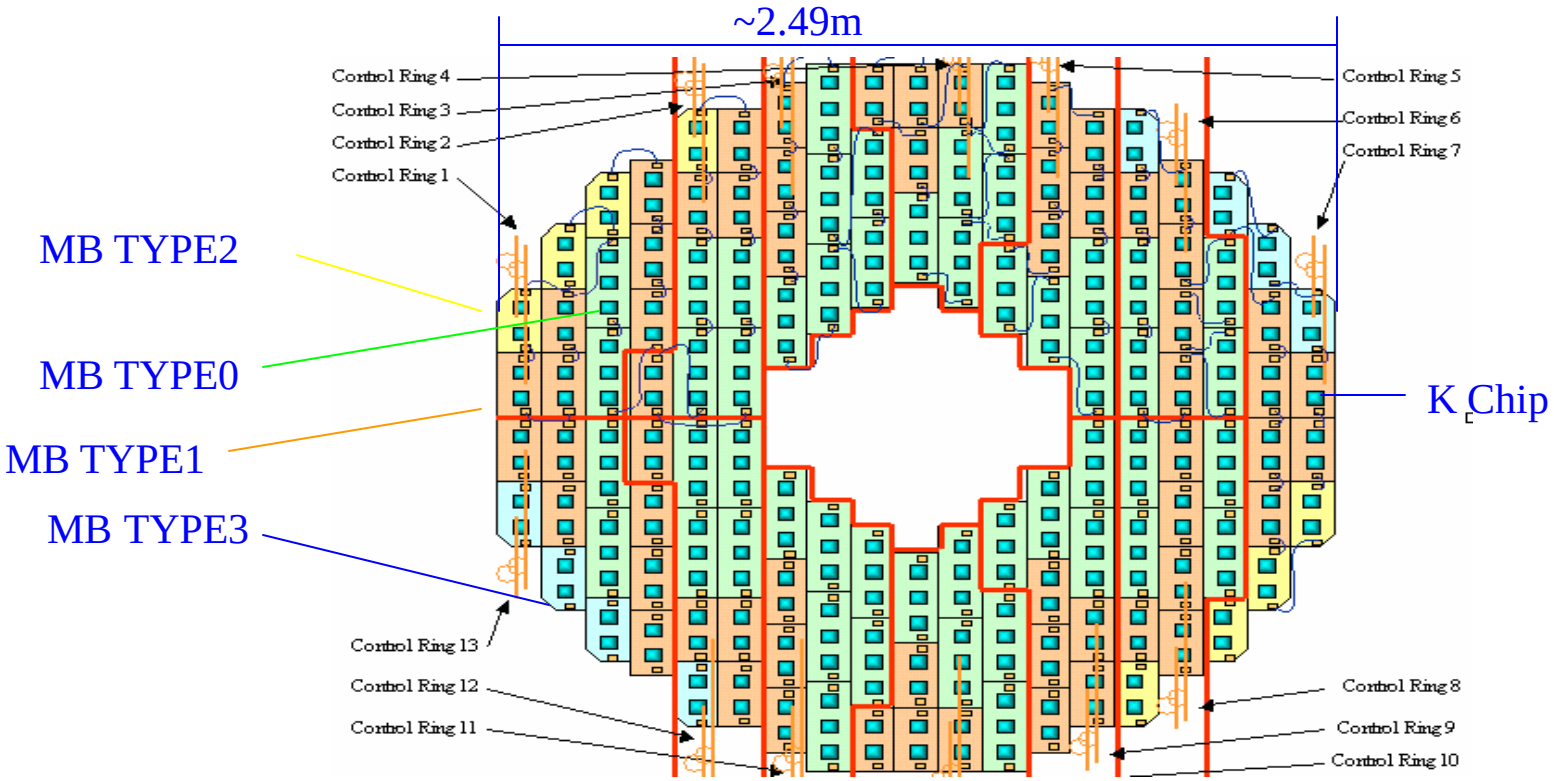
BARC closely collaborating with CERN on

DDU(Detector Dependent Units) Electronics for Si-PSD.

Si-Preshower Detector

Wafer	Geometry/Design	Electrical
4'' Float-zone Si N-type, <111> t=320±20μm Single-side polished r~4.0±0.5 kW-cm	Length:63±2.0mm Width:60_0.1mm No. of strips = 32 Strip-pitch = 1.90mm p^+ strip-width = 1.8mm p^+ strip length = 60.82mm Al strip-width=1.8mm (MO=10μm on both sides) n^+ layer thick>2.5μm	Full depletion Voltage $55<V_{fd}$ x$(0.32/t)^2$ 150V Breakdown Voltage Cat.1:V_{br}>300V Cat.2:V_b>500V Leakage current Total:<5μA at V_{FD} <10μA at 300V Strip-by-strip Max.1 with I>1μA V_{FD} Max.1 with I>5μA at 300V

Pre-Shower Disc

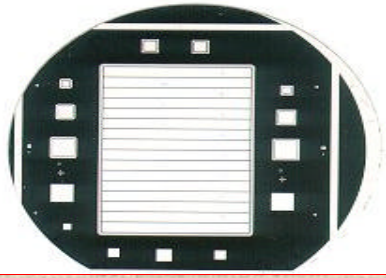


Total 124 x 4 = 496 Mother boards

INDIA

BARC SILICON STRIP DEVELOPMENT FOR CMS

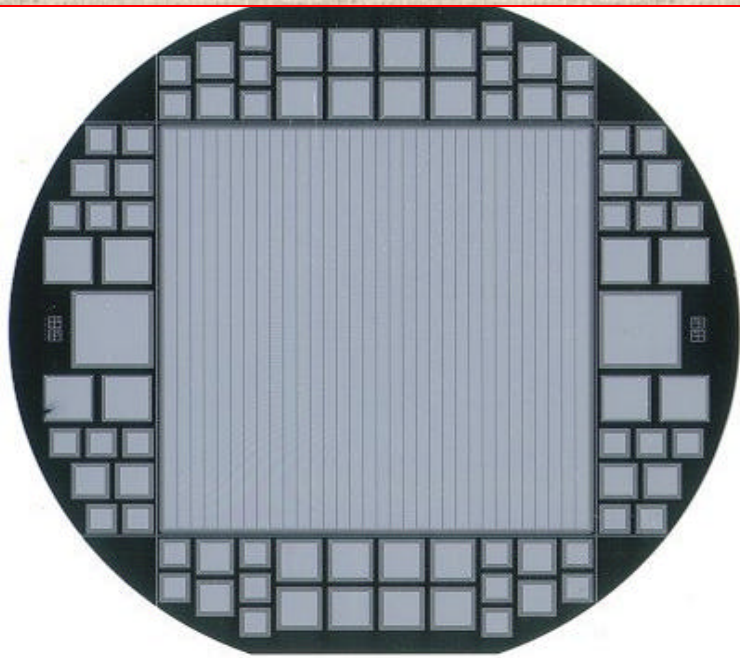
CEERI PILANI & BEL BANGALORE
TECHNOLOGY
AND FABRICATION PARTNERS



SILICON STRIP FROM CEERI PILANI

KEY SPECIFICATION

32 STRIPS
> 300V BREAK DOWN VOLTAGE
< 10-20 nA LEAKAGE CURRENT
RAD HARD
63mm x 63mm
PROTOTYPING DONE
PRODUCTION STARTED
TO SUPPLY 1000 DETECTORS
TO CERN



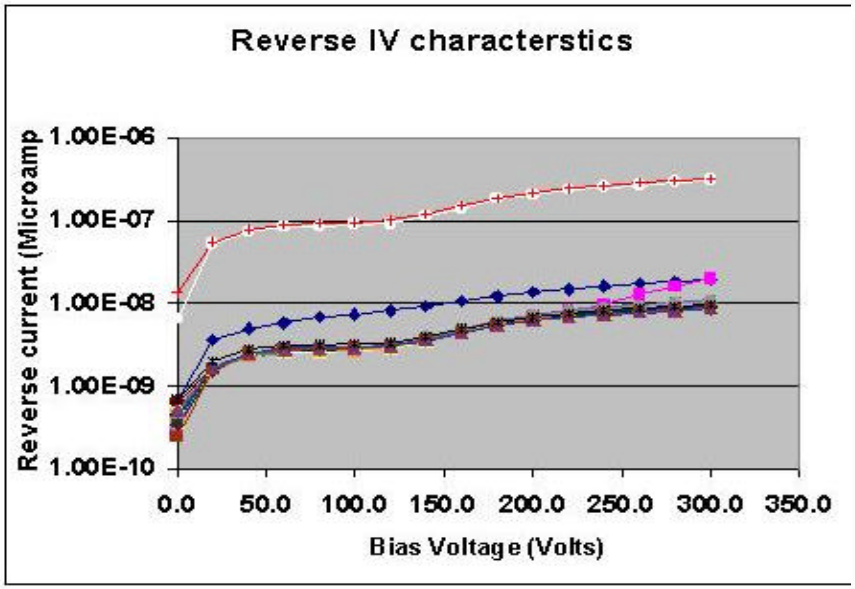
http://cmsdoc.cern.ch/cms/ECAL/preshower

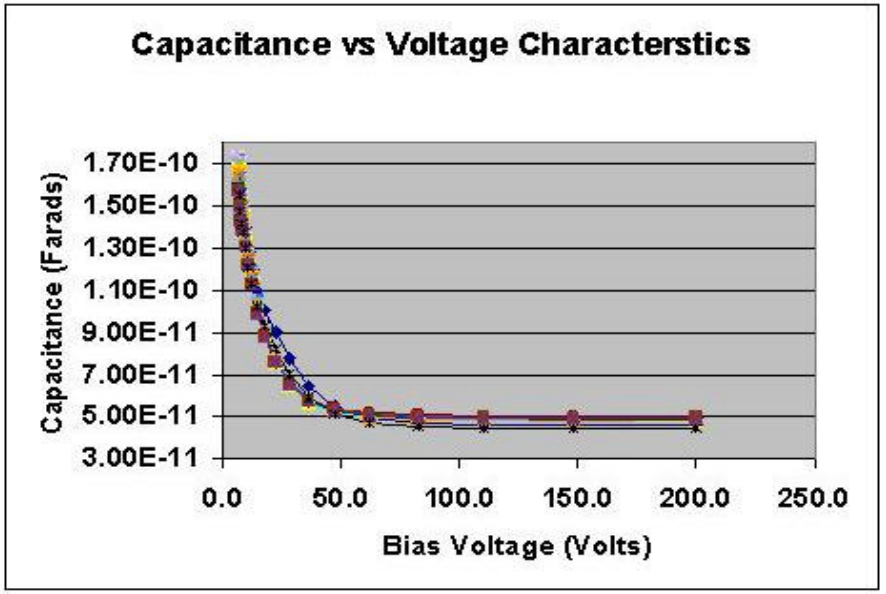
SILICON STRIP FROM BEL

Detector Testing at BEL

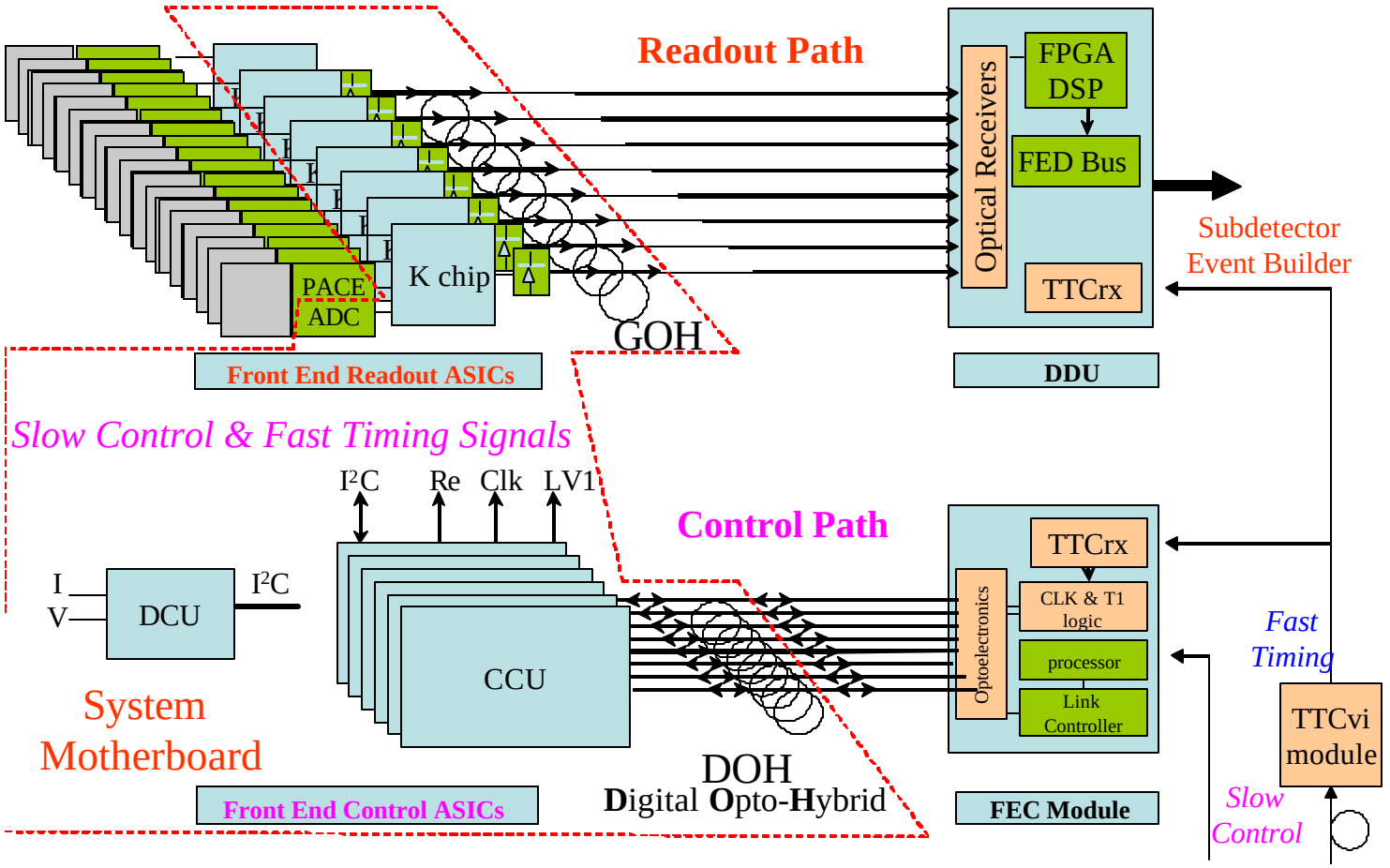
Visual inspections	Microscope
Mechanical measurements -width & length thickness	 Jig Comparator
Electrical Meas. For each strip I-V & C-V	Both at DU and BARC Systems (based on Lab VIEW)
Noise Meas. Electrical calculation ? Depletion Voltage for strip, ? Breakdown Voltage for strip ? Full Depletion Volt of sensor ? Breakdown voltage of the sensor ? Current at V_{fd} and 300V	Through I-V Measurement Lab VIEW based analysis Software provided by CERN

Typical IV and CV Characteristics of a Silicon Sensor Fabricated at BEL





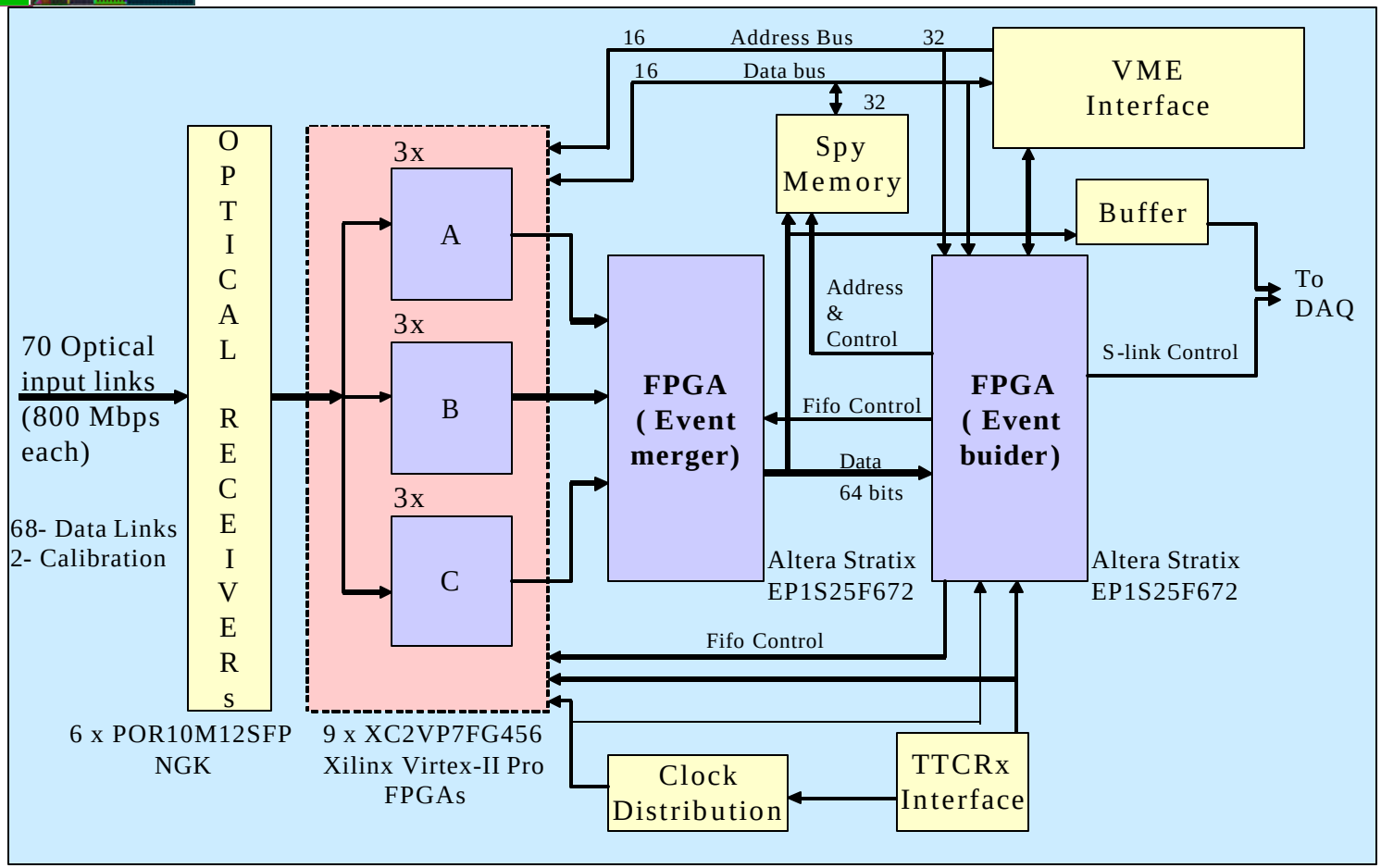
Preshower Readout Architecture



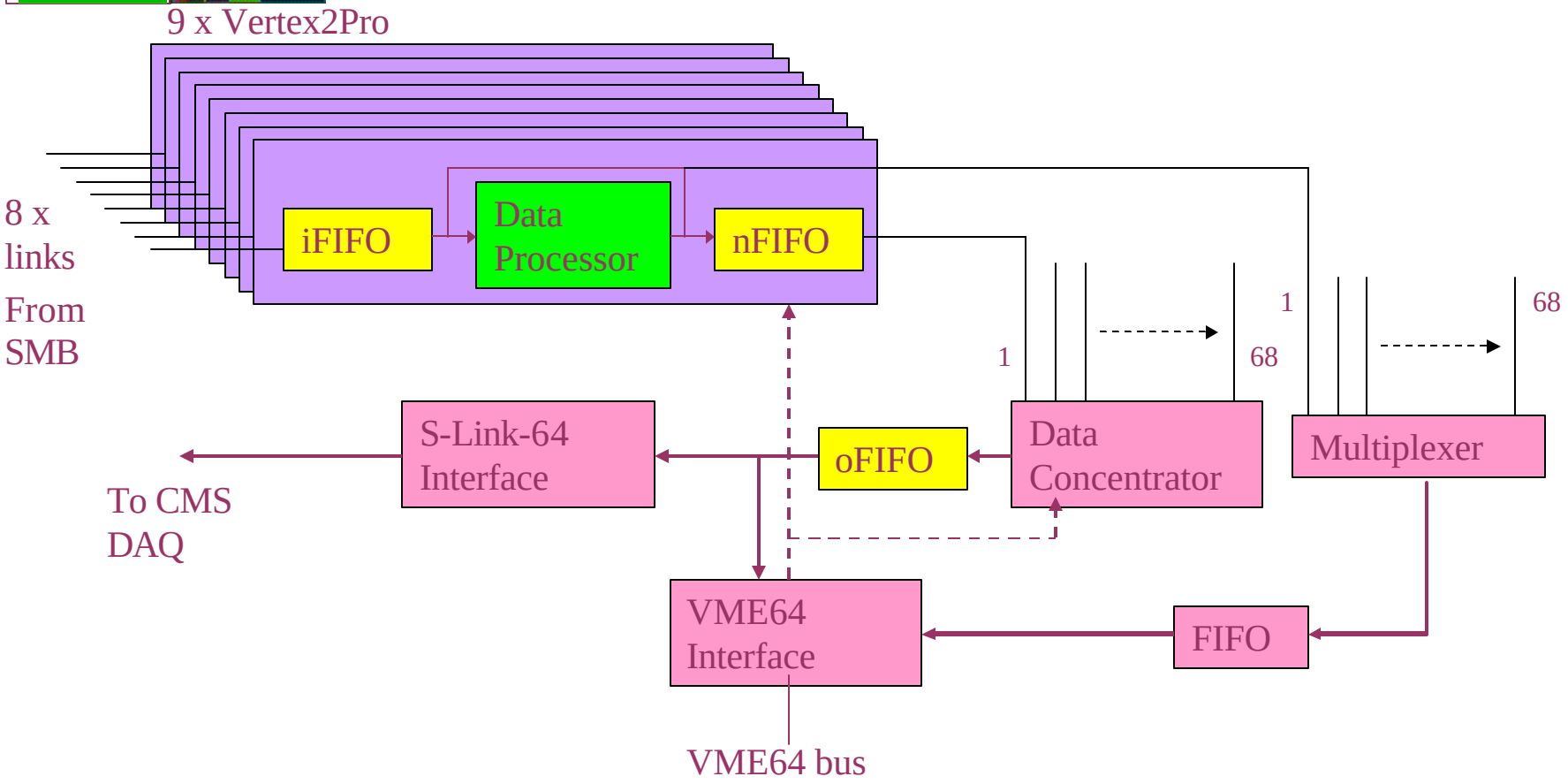
DDU Functional Requirements

- Optical to electrical conversion & de-serialization of incoming data streams
- Integrity verification of incoming data packets/event fragments
- Data reformatting
- Data reduction
- DDU event formation
- Transmission of DDU events to the global DAQ through the S-Link64 interface
- Transmission of spying events to the local DAQ through VME interface

Data Concentrator Card (DCC)



DDU Architecture in DCC



Si-PSD Milestones

Milestones

- **2001: Old size (60 mm x60 mm) detectors:**
  Acceptable yield of Si PSD starting from wafers (>50%)
- **2002:New (production) size (63mm x63 mm) detectors:**
  Also made successfully.
- **2002-3:100 Wafers processed in PRE-PRODUCTION run.**
  - **Excellent Detector Performance**
    (Low Leakage Current , High Uniformity)

Production of PSD began in 2003 & 100 Ready
& 1000 to be Completed by 2004/05

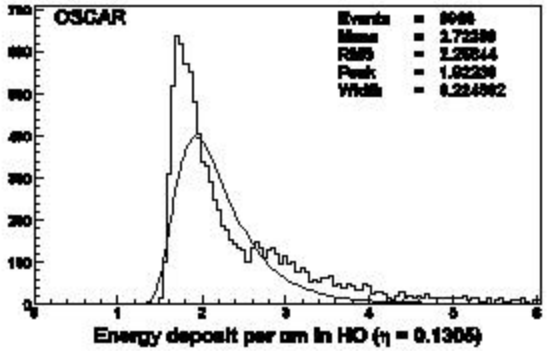
BARC to Contribute for Design & Development of DDU
& Produce ~ 50 Modules for Si-PSD

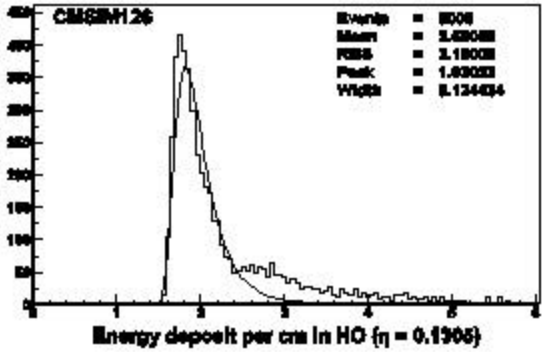
Software & Simulations

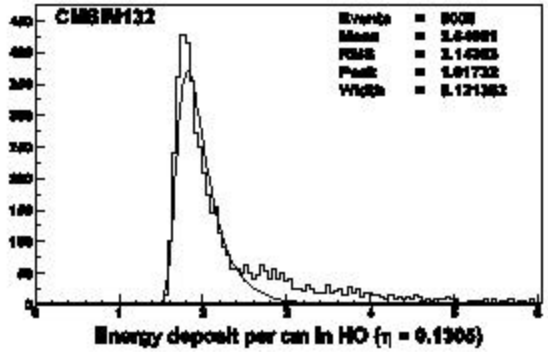
Software and Simulation

- Major contribution to CMS core-software effort:
  - Design & implementation of Object Oriented Detector Package
  - Development of tools for CMSIM & OSCAR
  - Evaluation/Optimisation of CMS tracker
  - Validation of the GEANT4 package (hadronic -shower)
  - Studies of Hadron Calorimeter
  - Using Test Beam Results Fixed Simulation Modules

Energy deposit in all HO layers







1 MeV γ cut for general tracking media

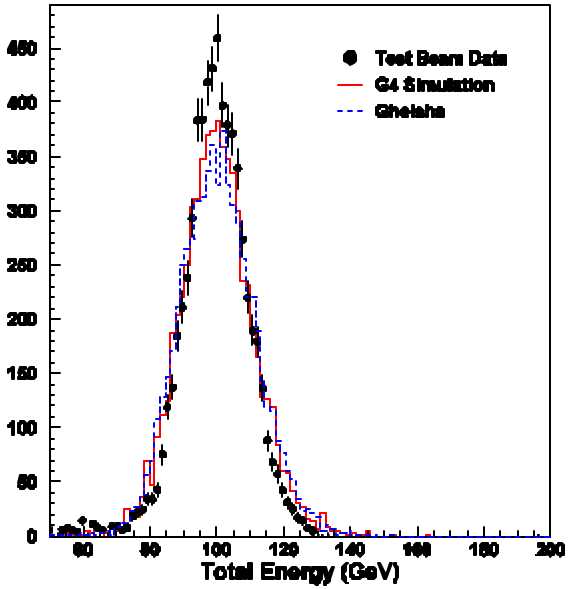
CMS

August 2003 Sunanda Banerjee

Geant4 Validation

Energy Measurement

- For a configuration with HCAL alone:
  - Convert energy deposits in terms of MIPs using muon data
  - Weigh the energy deposit in each layer by the absorber thickness in front
  - Normalise to beam energy using 100 GeV pion data



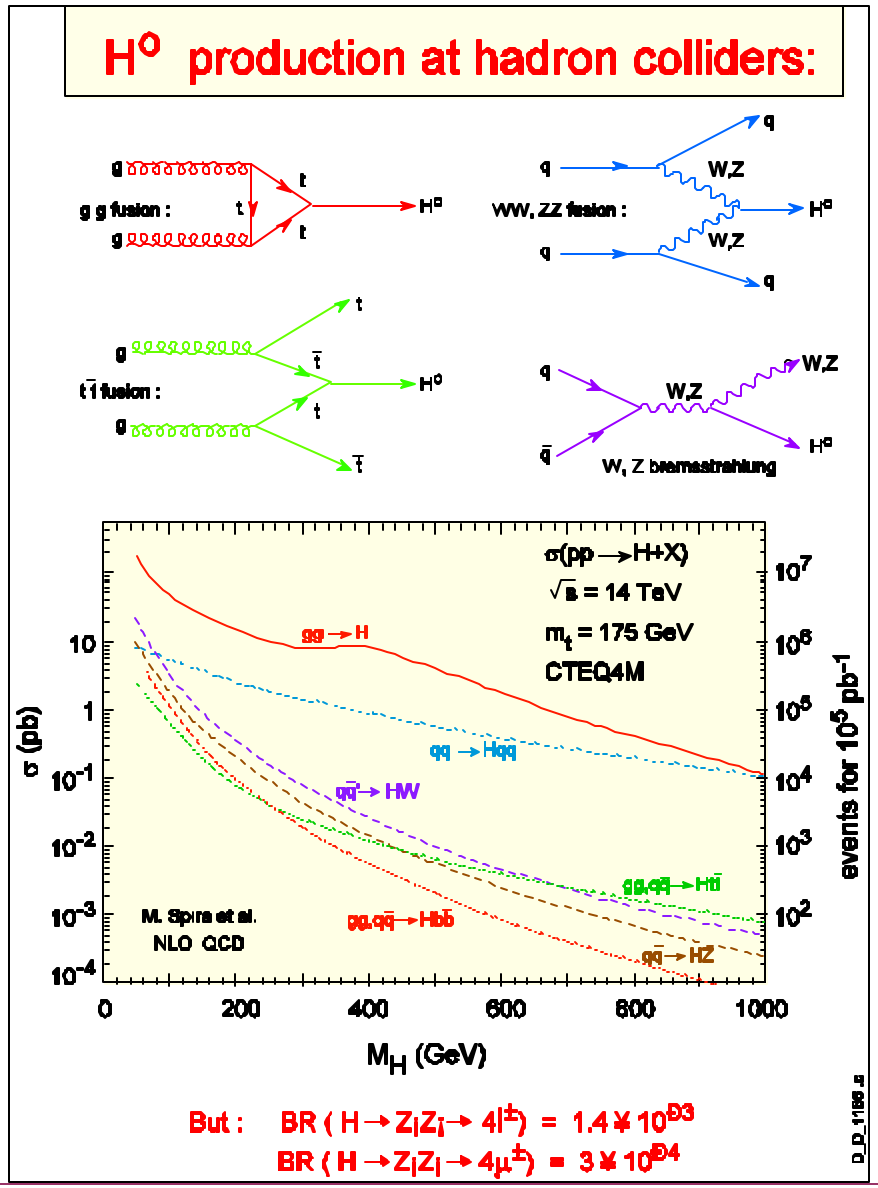
India-CMS Physics Simulation

? Physics Simulation have been done for

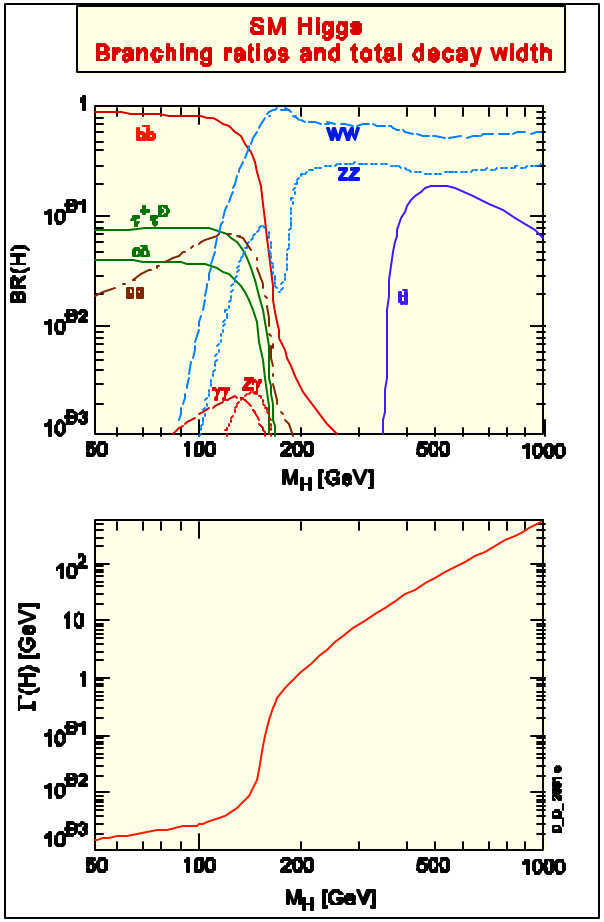
- Search for SM Higgs
- Invisible Higgs
- Charged Higgs(in Top Decay)
- Direct photon production
- Study of Top Quark
- Study of Compositness

About to launch on coordinated & comprehensive physics Simulation programme.

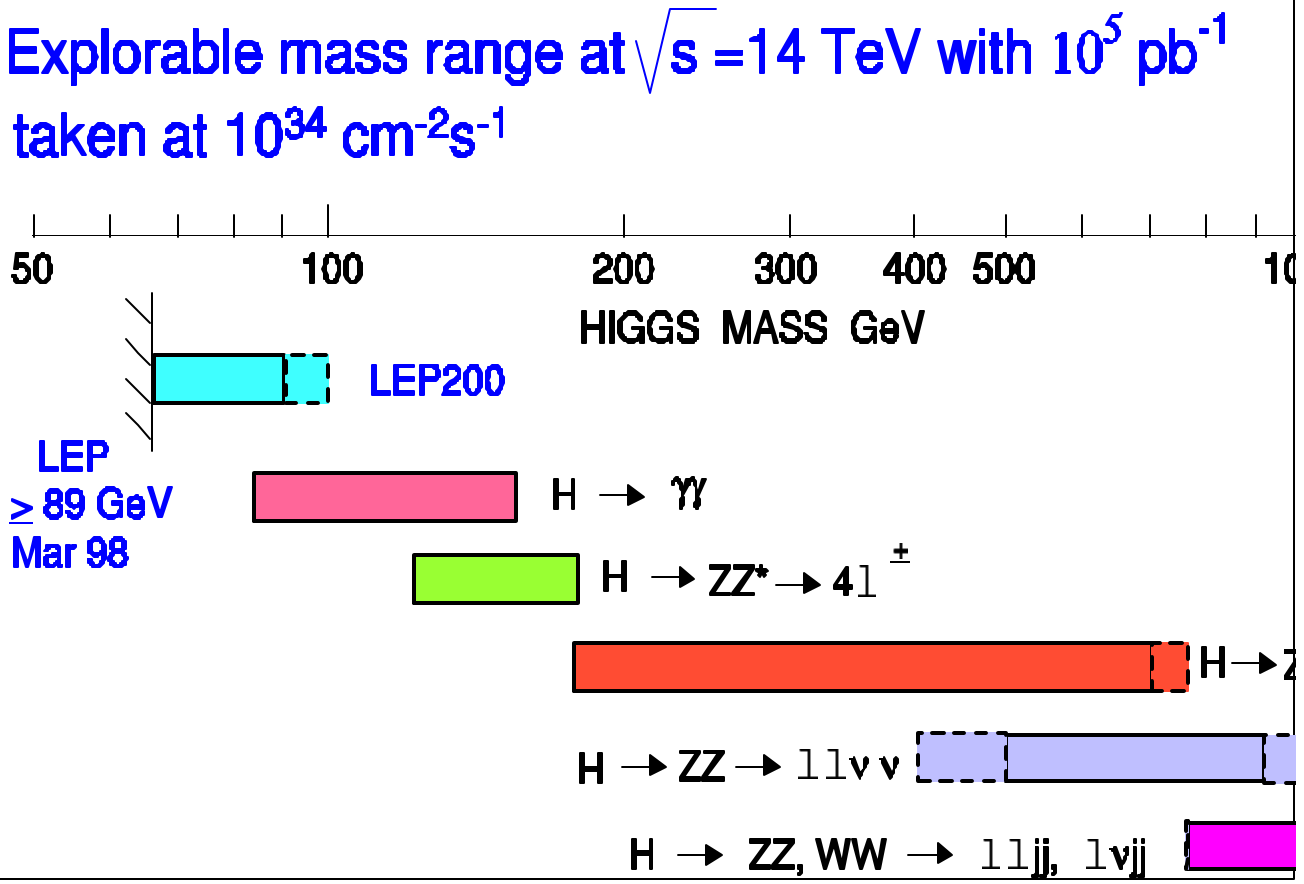
H^0 production at hadron colliders:



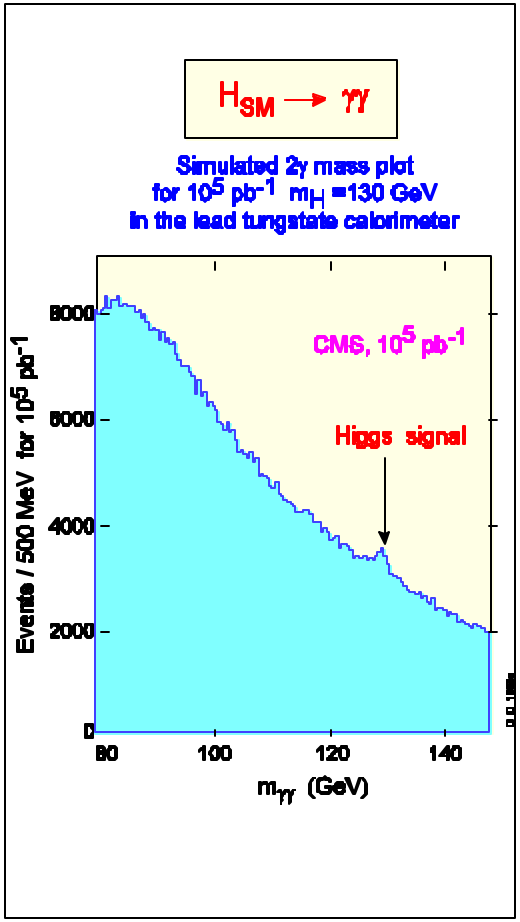
HIGGS Branching Ratio



SM Higgs Search in CMS



HIGGS


$H_{SM} \rightarrow \gamma\gamma$
Simulated 2γ mass plot
for 10^5 pb^{-1} m_H =130 GeV
In the lead tungstate calorimeter
CMS, 10^5 pb^{-1}
Higgs signal
Events / 500 MeV for 10^5 pb^{-1}
8000
6000
4000
2000
0
80
100
120
140
$m_{\gamma\gamma}$ (GeV)

FUNDING SITUATION

- **Funding Issues**

➢CMS Construction

Revised Overall CMS Estimate : 513 MCHF (M Swiss Francs)

India-CMS Contribution : 4.5 MCHF

150 MILLION RUPEES

Detectors = 3.5 MCHF

Common Project-magnet = 1.0 MCHF

➢Maintenance & Operations (2002-07)

Estimate of Common Collaboration M&O: 19 MCHF

Based on No. of Scientists (Ph.D.'s): 2.3%

Indian Contribution : 440 kCHF

M&O Contribution towards detectors (H.O. + Si-PSD) = 163 kCHF

Total India-CMS M&O (2002-07) : 0.7 MCHF

25 MILLION RUPEES

DST & DAE Funding

- **Indian Side Budget:**

  India-CMS funded jointly by

  - **Department of Science & Technology &**
  - **Department of Atomic Energy**

  220.5 Million Rupees

  + Cost of M & O

  + Per Diem Support for CERN visits

  For the purpose of

  Testing of Detectors

  Installations

  Physics Simulations & Software

  Meetings, etc.