Position Monitoring System for the CMS Tracker at CERN, Geneva

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PAEC

NEXT MACHINE: **LHC.. Same Tunnel as LEP, expected online 2006-7**

WILL HAVE FOUR DETECTORS

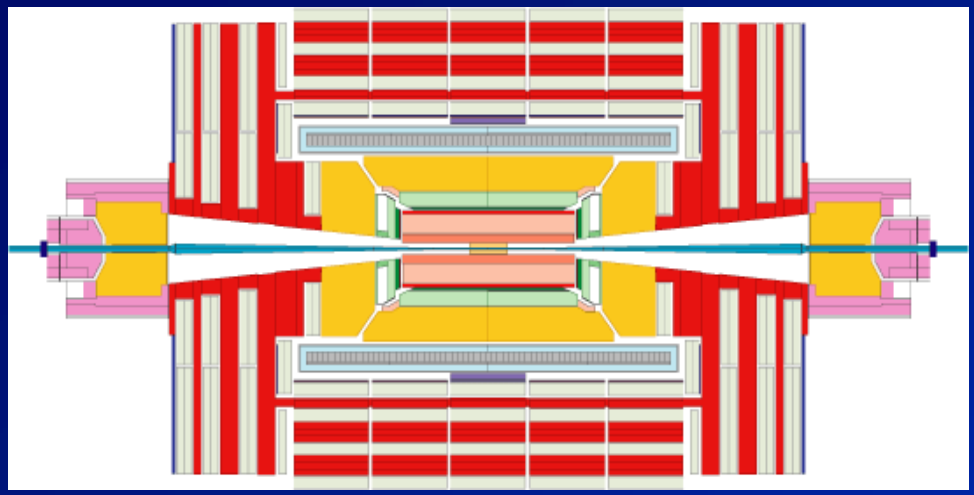
CMS & ATLAS : **p - p Beam expts (14 TeV each),**

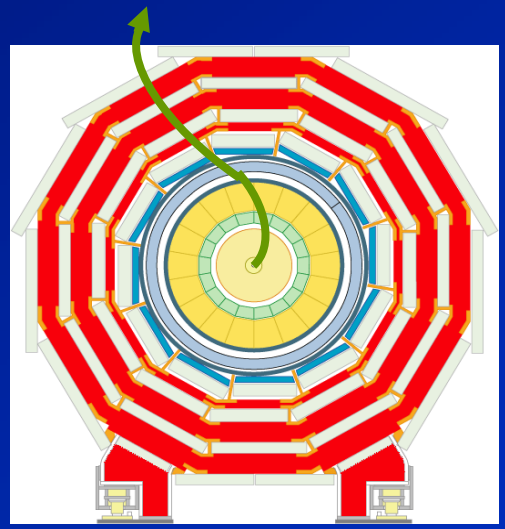
ALICE : Heavy Ions (Pb, 1250 TeV)

LHC_B : **Bottom Quark Physics, Violations of matter / anti-matter symmetry**

1 TeV ~ the energy of motion of a flying mosquito. What makes the LHC so extraordinary is that it squeezes energy into a space about a million million times smaller than a mosquito.

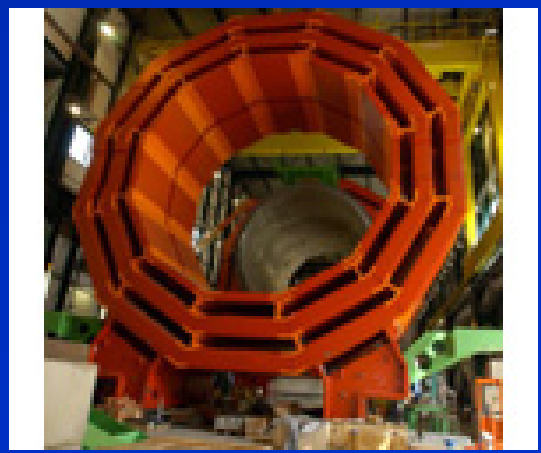
Other Views of CMS





Total Weight	:	12,500 Tons
Total Length	:	~22 metres
Diameter	:	~15 metres
Magnet	:	4 Tesla

- SC cable: 4.2^{o}K,
- 20 kilo Amps
- 27000 A / mm^2



Main Purpose of CMS: **p-p detector > Study physics underlying *breakdown* in the electroweak symmetry:**

Several possibilities: **Higgs mechanism favoured in the context of Supersymmetry**

Need to cleanly detect "signatures"

… photons, muons, electrons jets …

over large energy range and large luminosities

CMS is Optimised For Search of :

Higgs Boson ; CP violations; Top Quark Studies; Onset of Quark Gluon Plasma Formation

Luminosities $\geqq 10^{34}\ cm^{-2}\ s^{-1;}$ **Magnet 4 T, crystal e.m. calorimeter, powerful inner tracker**

Leads to precisions of < 1% at 100 GeV

TRACKER PERFORMANCE depends as much on

- **Intrinsic Detector Capability**
- **Stability of the Structure (Design… Materials … Stiffness / Stability)**

EXPECTED MOVEMENTS OF THE ASSEMBLED STRUCTURE ?

Displacements ?? Deformations ??

Remember : Very Heavy /Large Structure:

- **Will move / distort due to gravity, magnetic field, temp. gradients, differential expansions (e.g, Si, Steel, Al , CF, quartz) , moisture,**

EVEN THE LEVEL IN LAKE GENEVA ! ?

FOUR **mechanically independent components:**

~25,000 silicon strip detectors(A=210 m^2), connected to 75,000 APV chips;

There are 9.6 m readout channels, 26 m microbonds

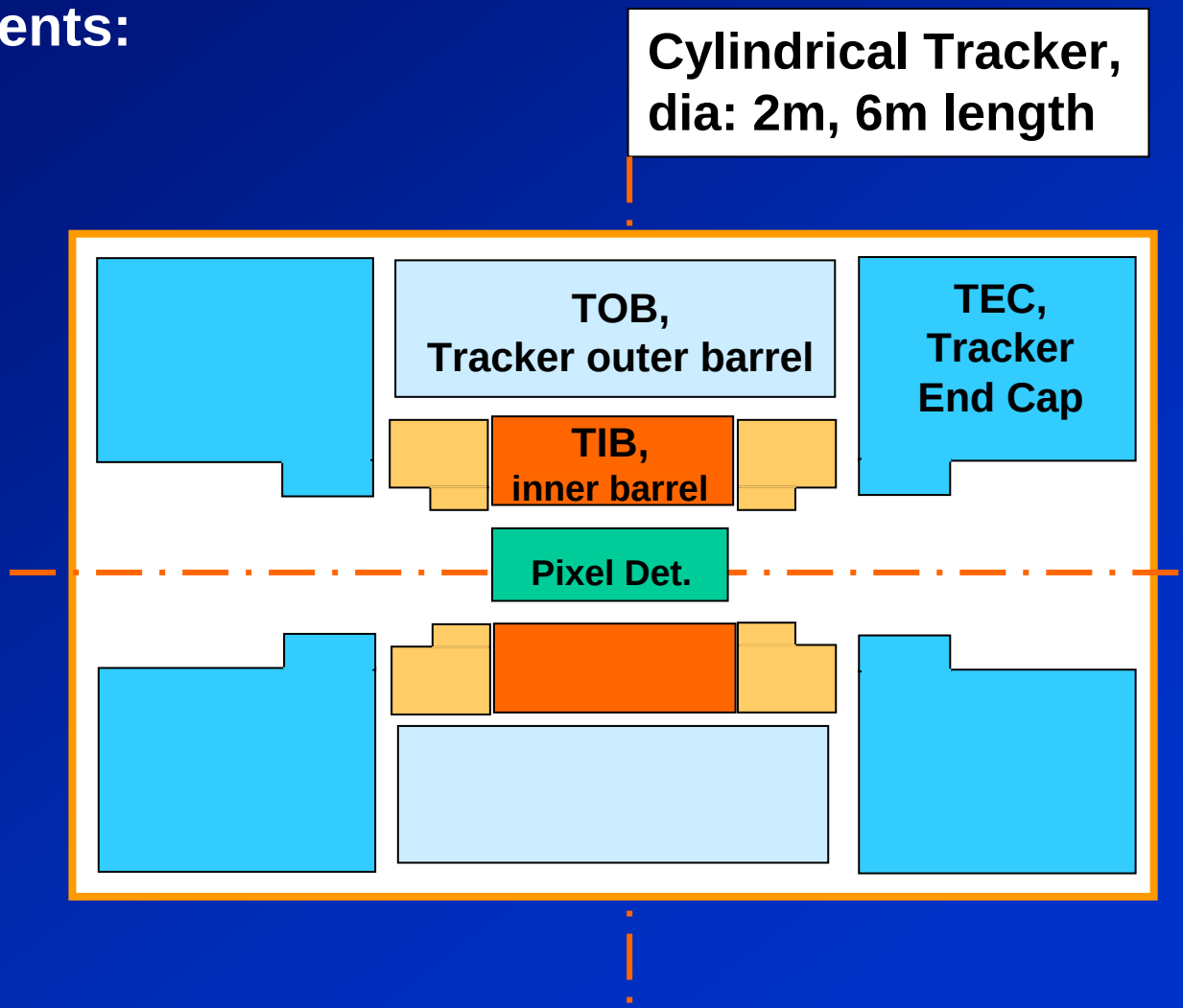
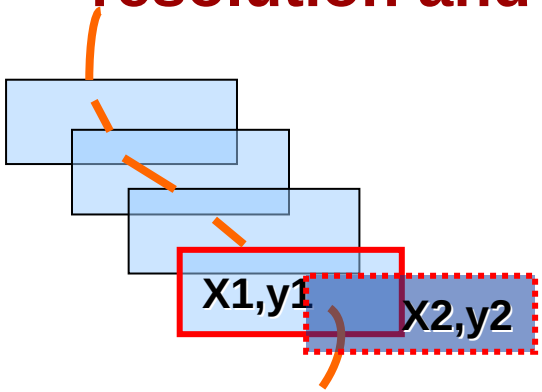
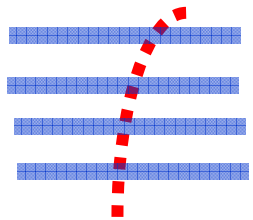
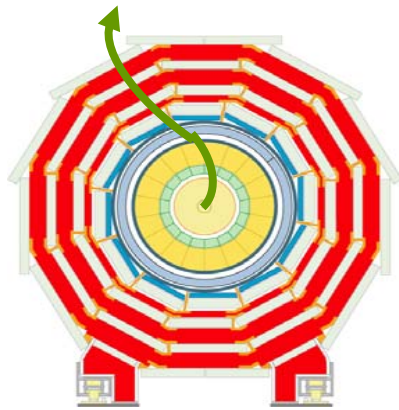


Fig 1: View along length of tracker cylinder

- **The single <u>most important feature</u> is the configuration designed for <u>high momentum resolution</u> of the muons.**
- **Places a very stringent demand upon the spatial resolution and therefore the detector alignments.**







Each muon chamber: 3 superlayers >4 layers
Superlayers give Rϕ and Z co-ordinate

Muon Momentum related to bending in transverse plane > mag. Field.

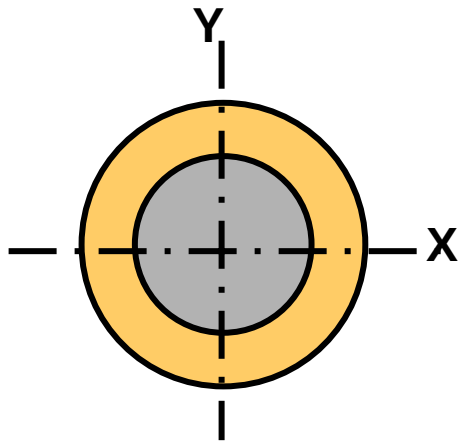
Rad. of curvature ρ(m) = p_t {GeV/c} / 0.3 B{T}. ρ obtained from the muon trajectory sagita 's' after travelling distance 'd' by $\rho \sim d^2/8s$
Error in s > error in muon measurement.

$\delta s/s = \delta p/p \quad \alpha \quad \{\sigma_s(\text{mm})\ p_t\ (\text{TeV})\} / d^2\ (\text{m}^2)\ B\ (\text{T})$

Desired Precision and Expected Motions ?

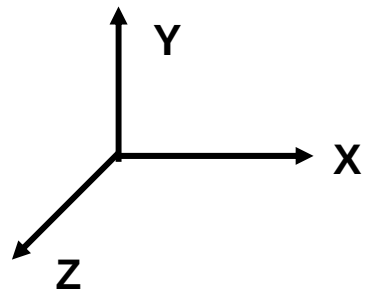
MUON BARREL CHAMBERS:

Precision: 150-350 microns in Rϕ,
250 microns in Z axis



Expected Motions (gravity + magnet):

- In X
  - + 0.21 mm / - 0.56 mm at top / bottom
  - + 1.8 mm / - 2.6 mm at centre right / left

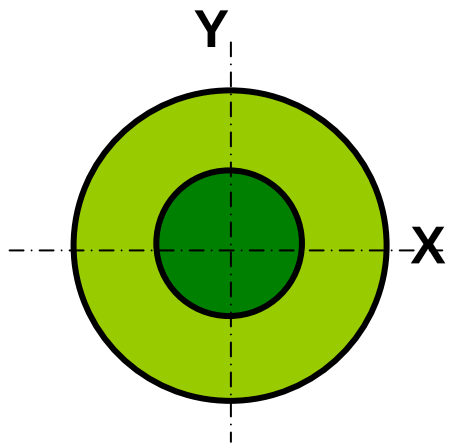


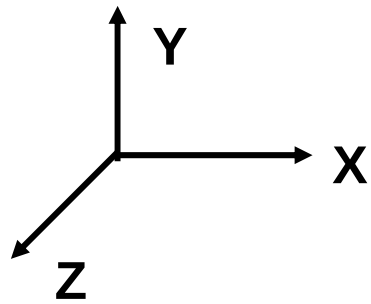
- In Y
  - - 4.1 mm / - 0.06 mm at top / bottom
  - - 2.2 mm / - 1.9 mm at centre right/ left

- In Z
  - +1.0 mm at Z-stops
  - + 0.2 mm for rotation around X

TRACKER: Required Precision:

Vertical Position mm	R (μm)	R ϕ (μm)	Z (μm)
200	100	15	500
700	300	15	500
1200	600	50	2000



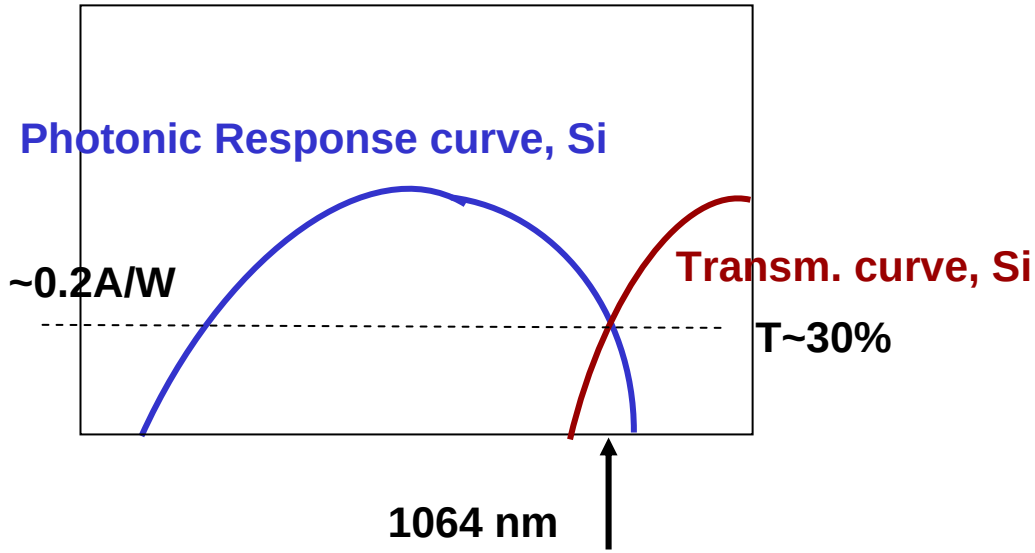


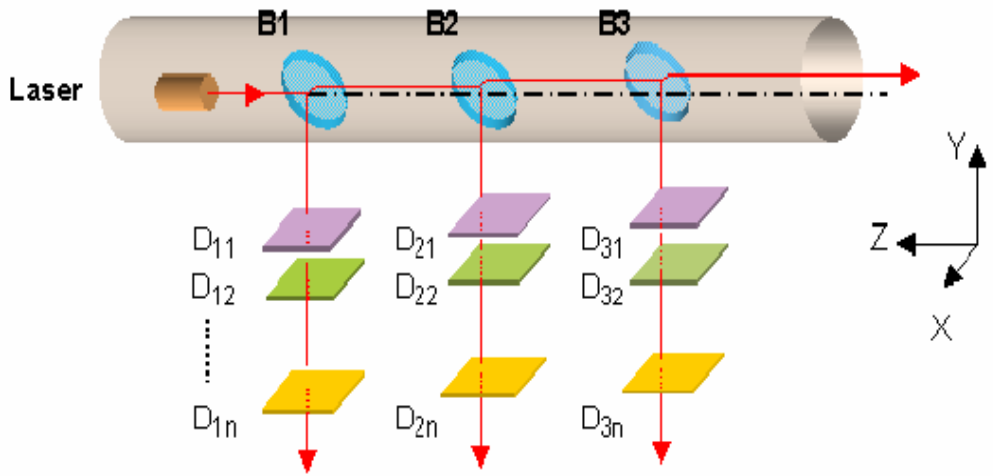
Max. distortion @ R=1200 mm:

- 0.314 mm at top & bottom

Key Features of the Position Monitoring System

The laser pulse produces photo-electrons in the silicon detector ; it is also transmitted. <u>The same electronic system</u> reads out the signal from the high energy particles as well as the laser beam.





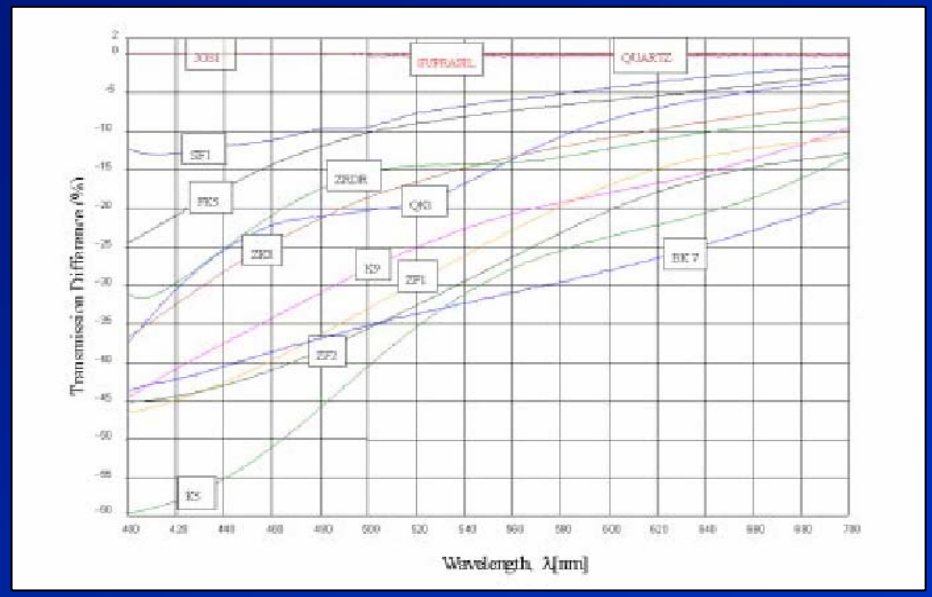
Few tens of femto-Coulombs of charge

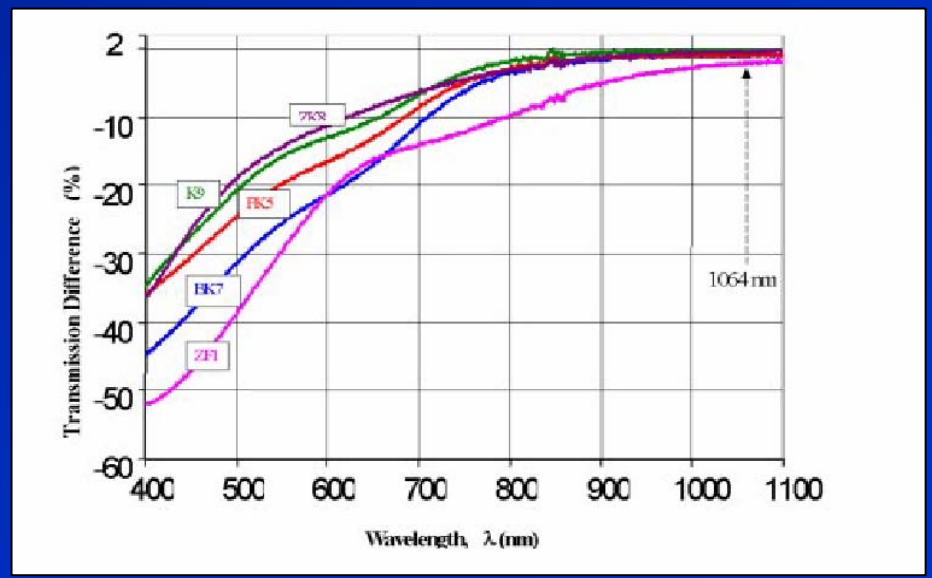
Radiation Damage ::

n fluence > 4 x 10^{14} /cm ^{2}

γ : 10 MegaRad

- 13 Diff. Glasses
- 3 Diff Optical cements
- HR / AR / Metallic Coatings
- Transmission recovery





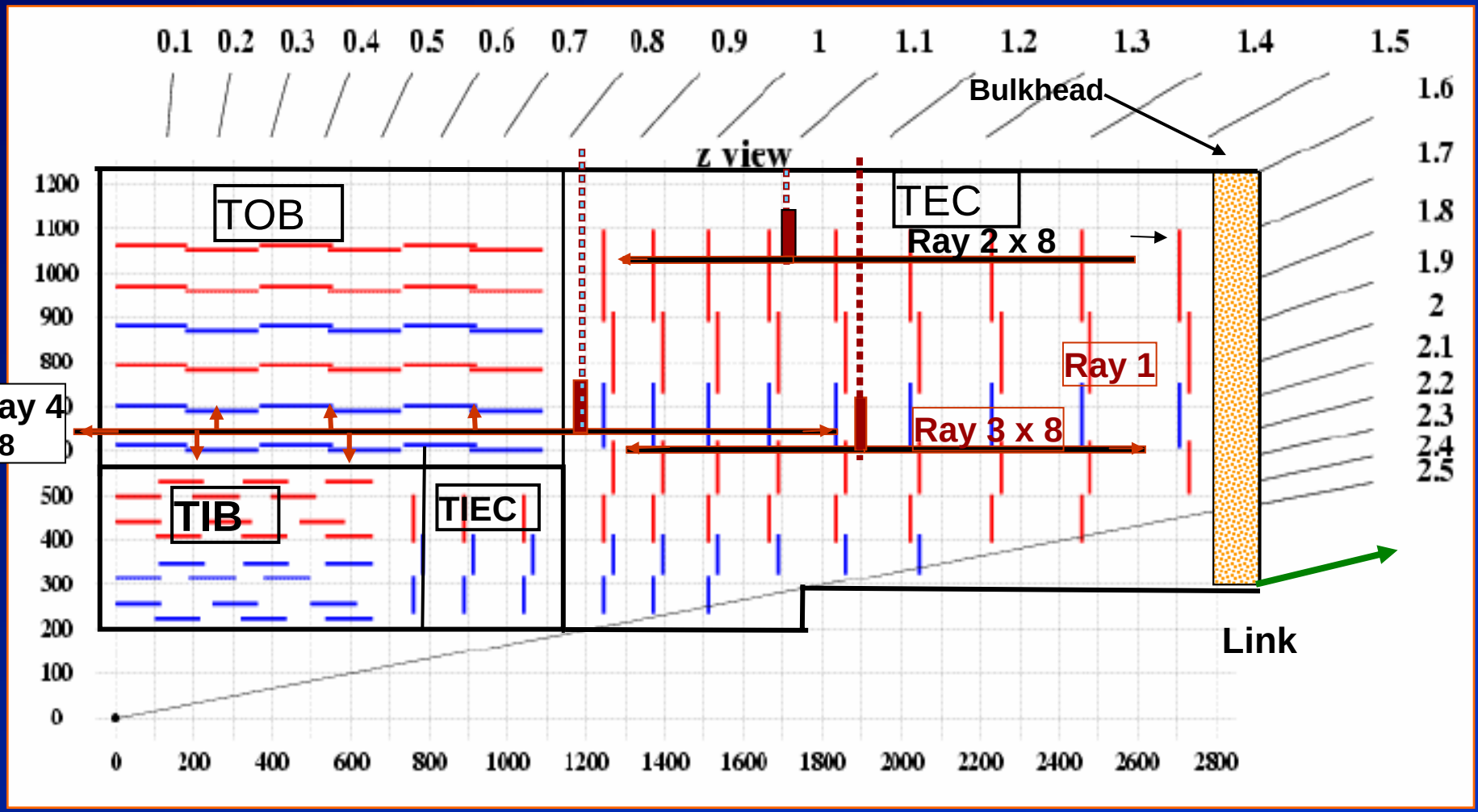
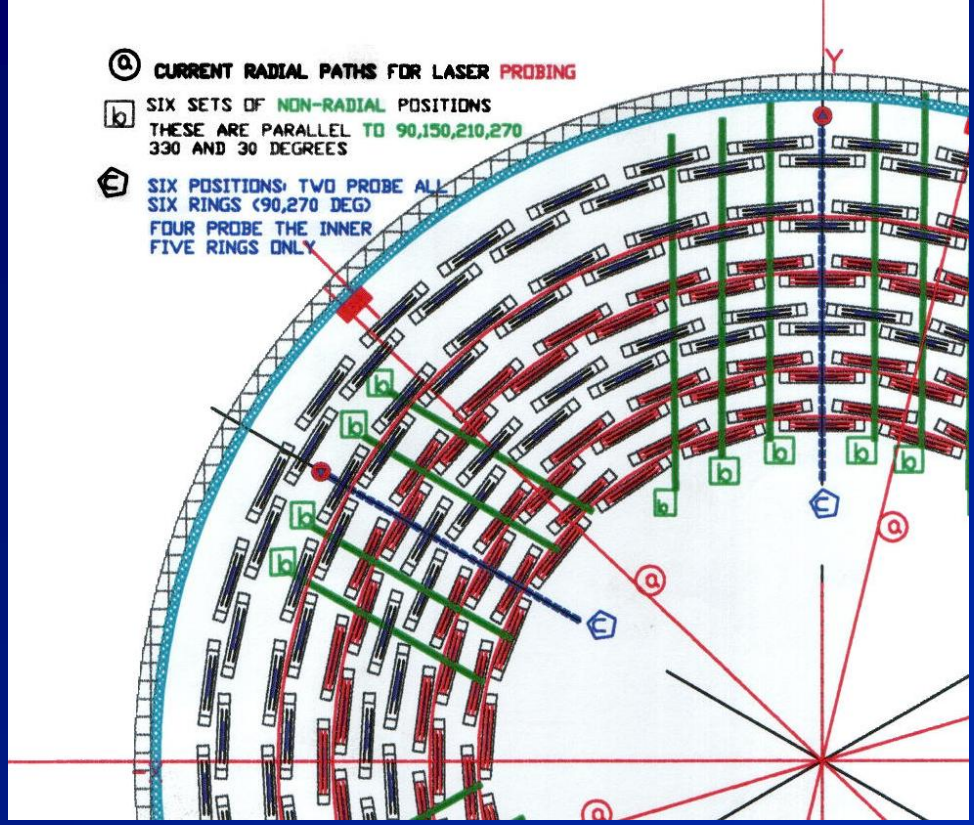
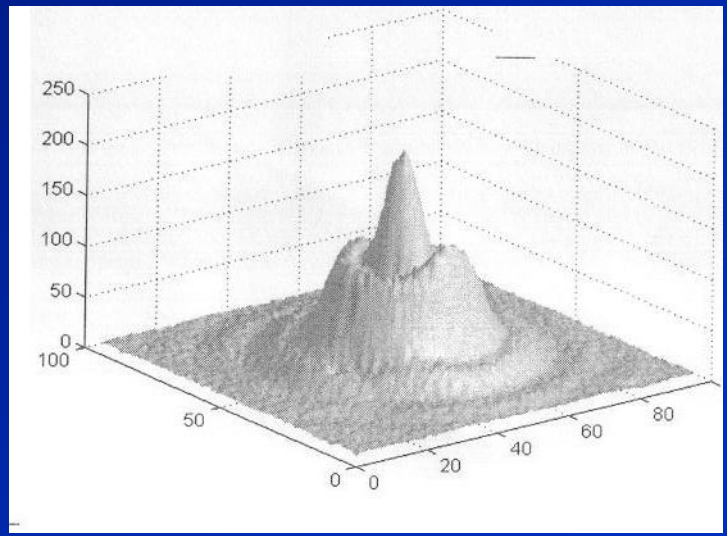


Fig 2: Overall View of the Alignment Modules and the Tracker Modules, showing detectors





Accuracy : heavily affected by the quality of the profile

Interference effects through successive Si can cause distortions >> Systematic errors.

USE LASERS WITH SMALLER COHERENCE LENGTHS

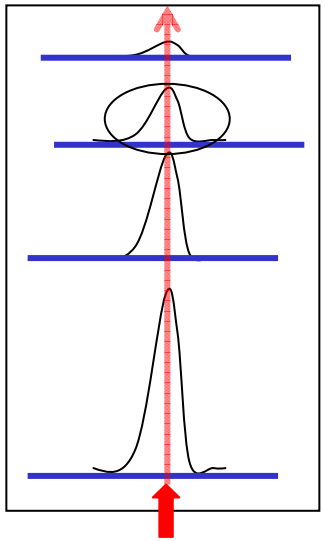
Quick Summary

- **Transmission of silicon sensors : max. number of crossable sensors? Depends on : R and T of Silicon; and the signal-range of the readout electronics. Anti-reflection coatings were investigated.**
- **Choice of Laser Wavelength: To optimise the induced signal.**
- **Light distribution system utilising optical elements such as beam splitters, prisms and fibres, proved its stability and linearity.**

Quick Summary (contd)

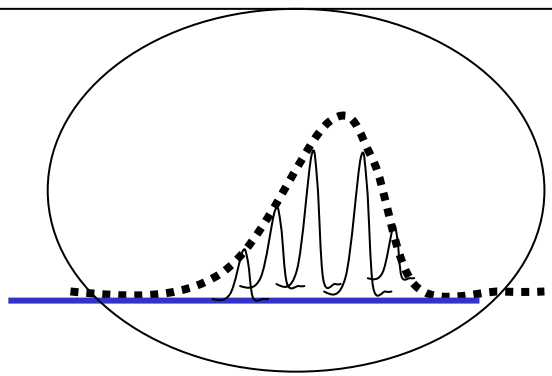
- **Choice and Optimisation** of optical components. Only Rad-Hard materials can be used. :: studied glasses, coatings and cemented optics were studied for the first time including tests of adhesion and abrasion of coatings.
- **Stability of a large-scale distribution system for laser** light. Will show you some results
- **Stability of carbon fibre structures** to possibly realize a stable reference structure, its (temperature variations, radiation, change of humidity,etc.) >>> (Portugal)
- Draw up Specs./ Design & Fabricate prototypes

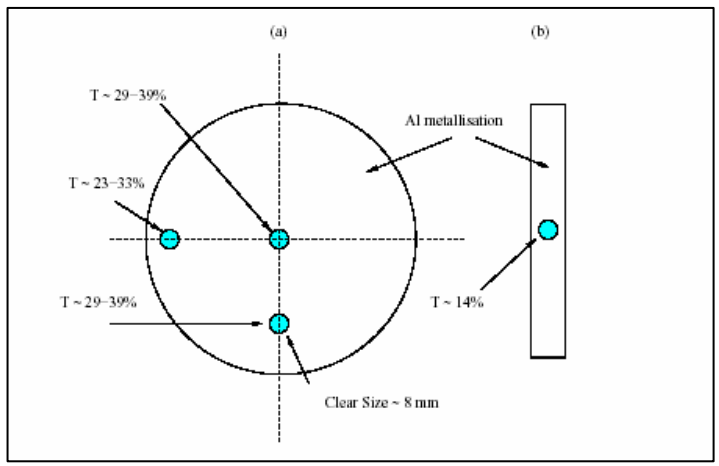
Fire the laser: Read the signal from several Silicon detectors at the same time

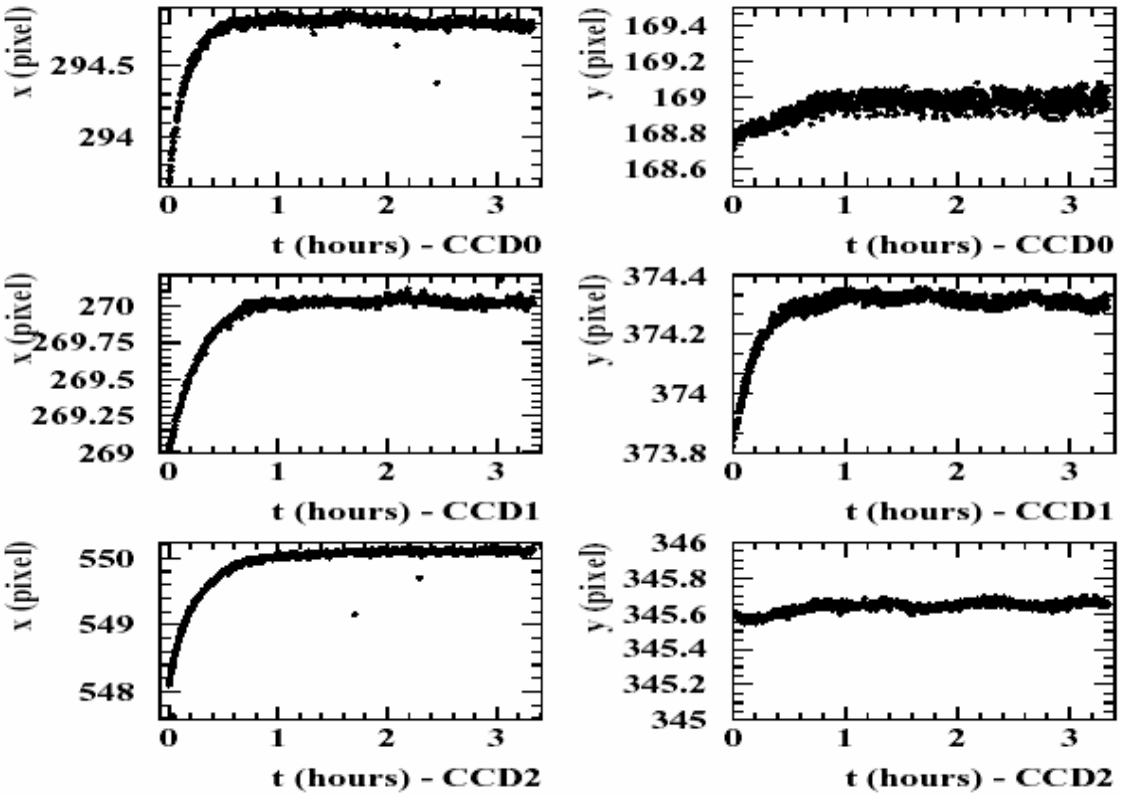


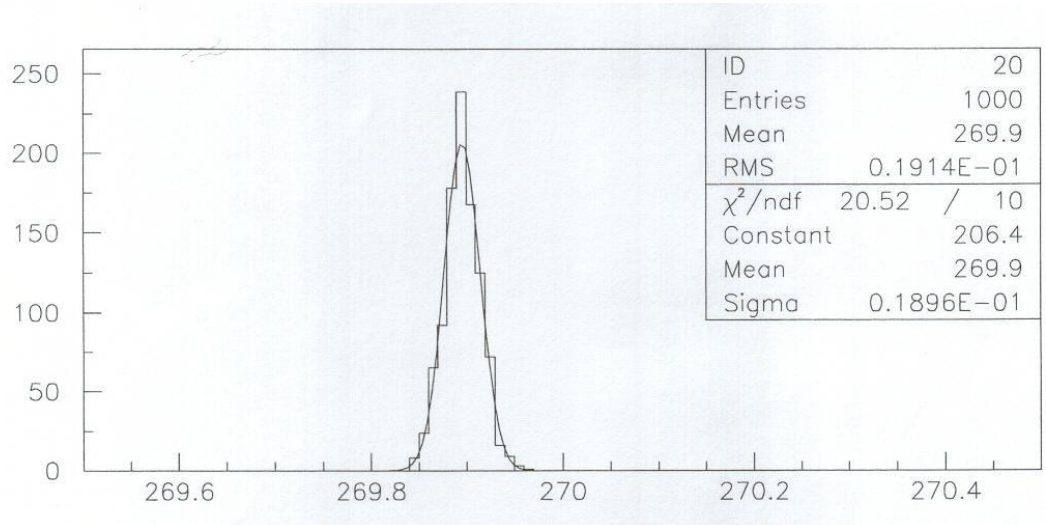
- **Laser passes through successive detectors:**
- **Read the laser position(c.o.g.) on each detector**
- **<u>One shot</u> gives many <u>relative positions</u> <u>of many detectors</u> at the same instant**
- **Repeat laser shots .. and the sequence again**
- **Continuously <u>monitor</u> the positions of these detectors**

Designed Anti-reflection coatings for the Si.. > 10 layers





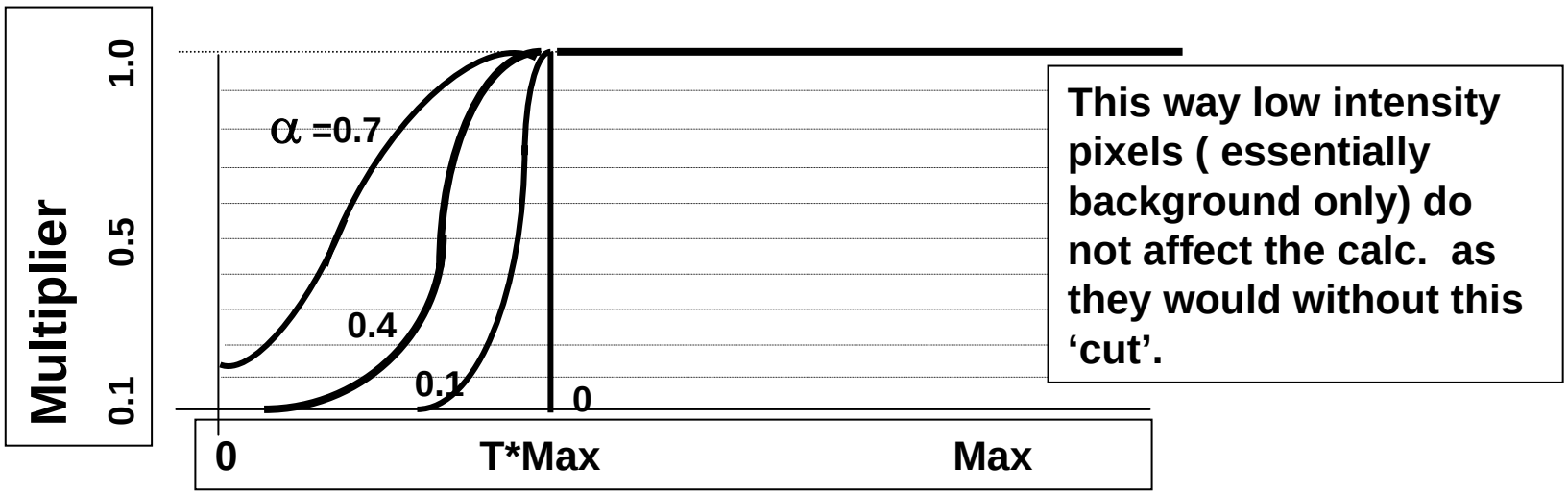

x (pixel)
294.5
294
0 1 2 3
t (hours) - CCD0
y (pixel)
169.4
169.2
169
168.8
168.6
0 1 2 3
t (hours) - CCD0
x (pixel)
270
269.75
269.5
269.25
269
0 1 2 3
t (hours) - CCD1
y (pixel)
374.4
374.2
374
373.8
0 1 2 3
t (hours) - CCD1
x (pixel)
550
549
548
0 1 2 3
t (hours) - CCD2
y (pixel)
346
345.8
345.6
345.4
345.2
345
0 1 2 3
t (hours) - CCD2


ID 20
Entries 1000
Mean 269.9
RMS 0.1914E-01
χ²/ndf 20.52 / 10
Constant 206.4
Mean 269.9
Sigma 0.1896E-01
250
200
150
100
50
0
269.6
269.8
270
270.2
270.4

- **CG Method : still requires <u>Image Treatment</u> to find the light spot position with <u>high accuracy</u>**
- **How to reduce the Noise & Improve Accuracy without loosing signal?**

1. The Multiplier Method: **Multiply each pixel by a factor before treating them with the simple CG method. The function is 1 for above a certain value (Max.T) and is given by**

exp -[(a-T.Max)/(T.Max. a)]^2 ... slope steepness given by α



This way low intensity pixels (essentially background only) do not affect the calc. as they would without this 'cut'.

- **The intrinsic resolution of a PMS based on a laser beam and a high resolution readout is better than 1 μm.**
- **Once the system is stabilised, the c.o.g. of the laser spot can be reconstructed with a resolution of 0.2 μm in X and 0.3 μm in Y provided the detector has a comparable intrinsic resolution.**

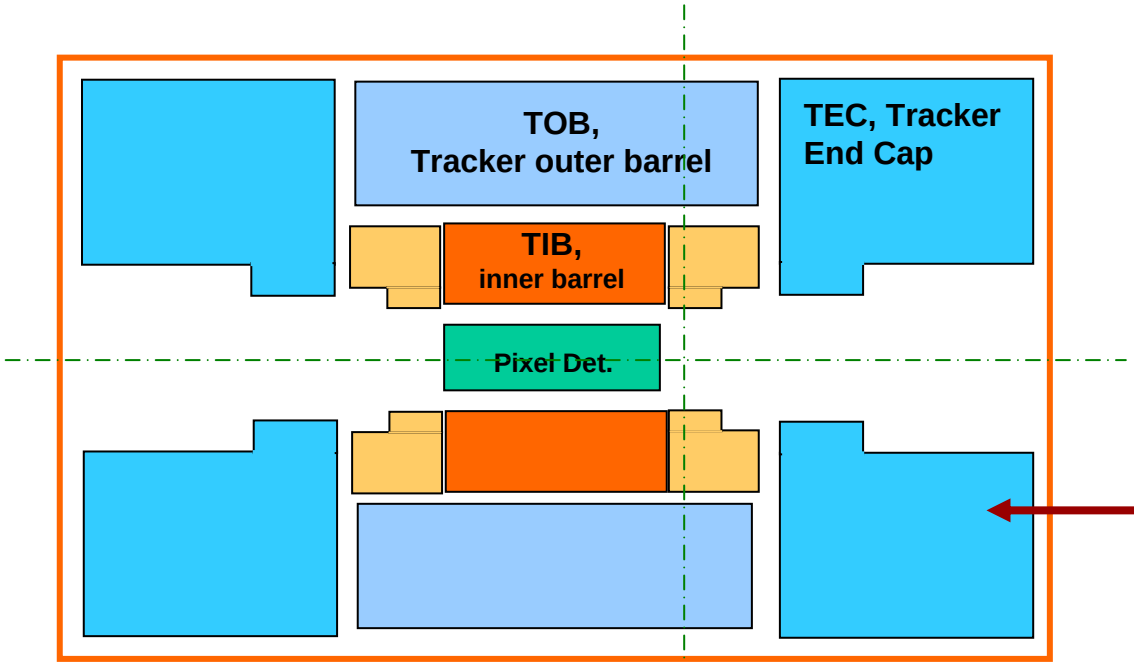
OPTICS LABS:

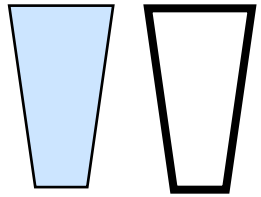
4 PERSONS AT CERN FROM OUR LABS.

HELPING TO ASSEMBLE THE TRACKER SYSTEM

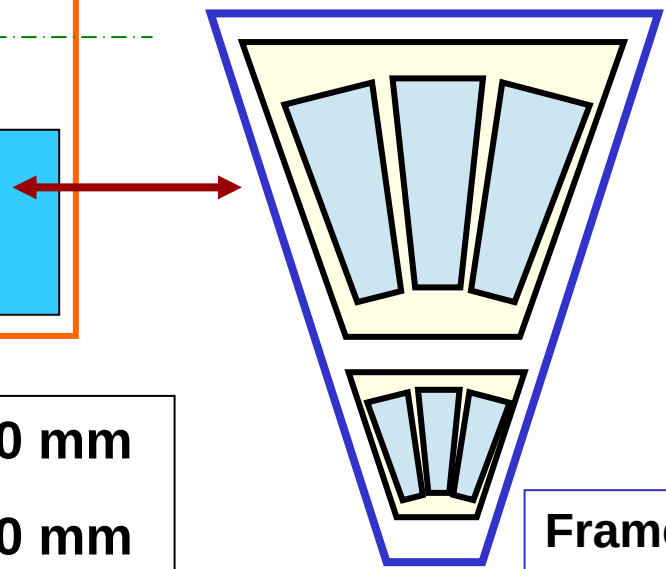
RWTH Physik. Instt (Aachen, Germany) our major partner

First modules being tested there before assembly at CERN





Detector to Frame



Si Detector to CF Frame	: 0.010 mm
CF Frame to Petal / Rod	: 0.020 mm
Petal / rod to support structure	: 0.020 mm

Quad. Sum: 0.030 mm

Frame to Petal (Rod) Petal to Structure

Beams run Parallel to Z-axis; Disc may rotate around Z ($\Delta\Phi$) or move perp. To Z (ΔX, ΔY)> Measure the Φ co-ordinates of the laser spot.

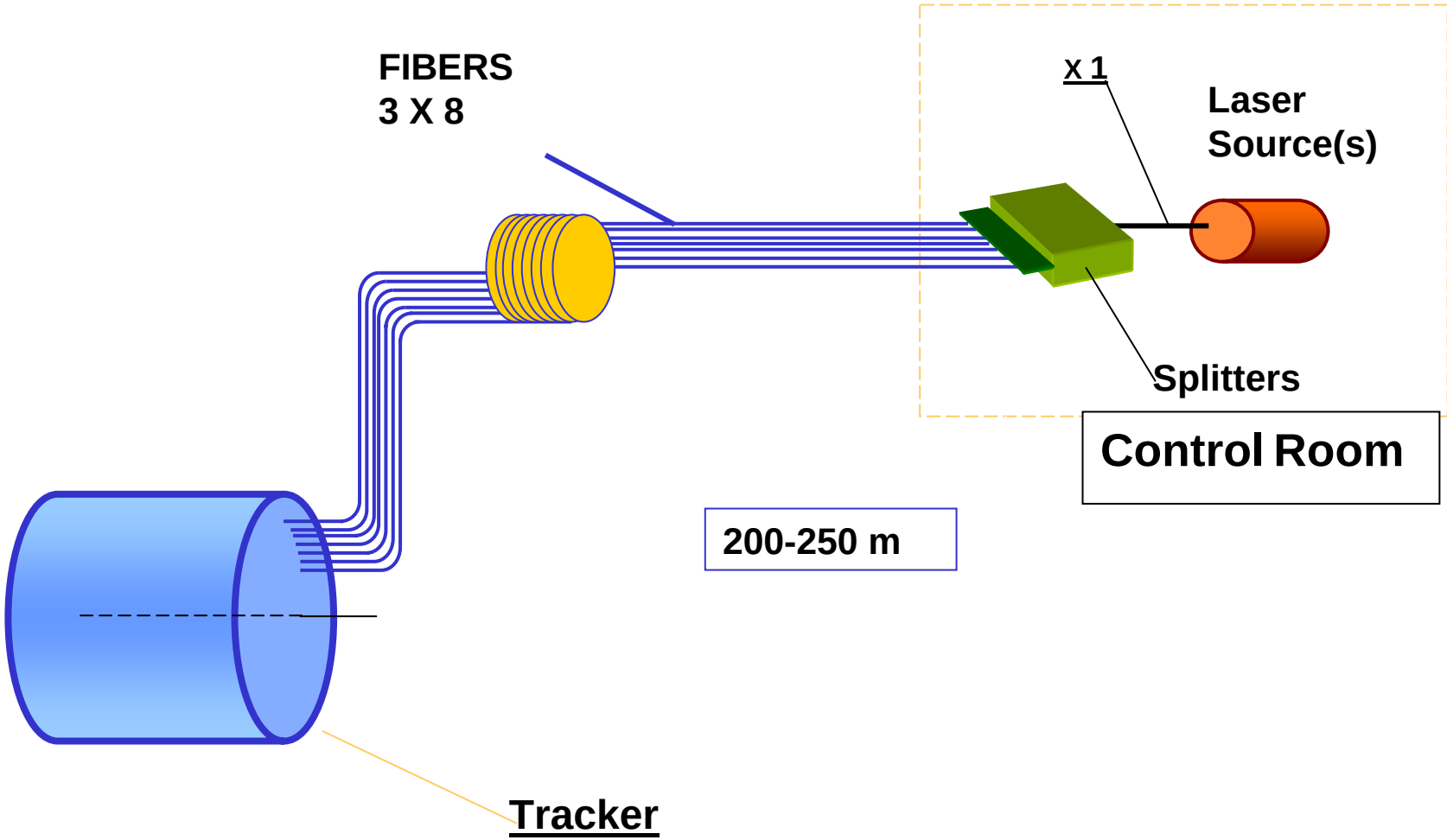


Fig 3: Distribution of the Lasers and Fibers for one Half of the Tracker

Option 2:---Use One Mother Laser, 2nd Laser as Backup
Split into 40 (or 20 + 20) beamlets in the control room
Send total 16 + 16 = 32 fibers on to Patch Panel / TEC
Send 8 or 4+4 fibers for Ray 4 along with other services to the TOB Optical nodes.

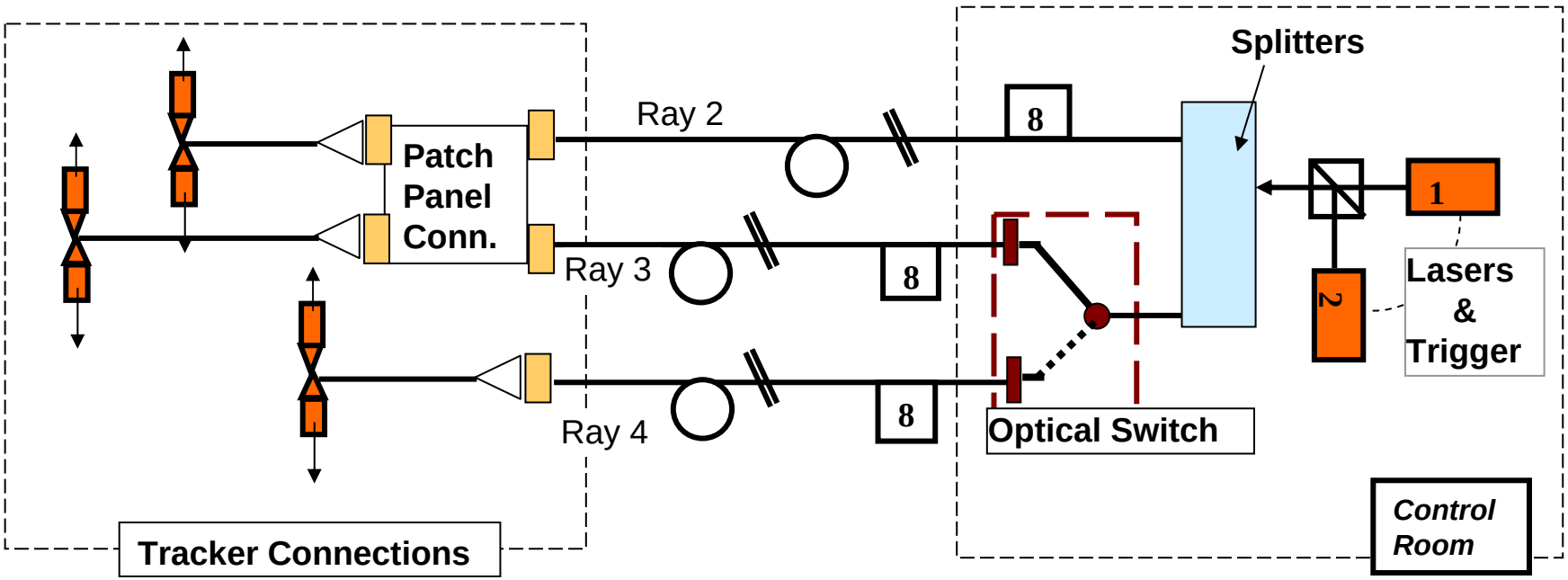
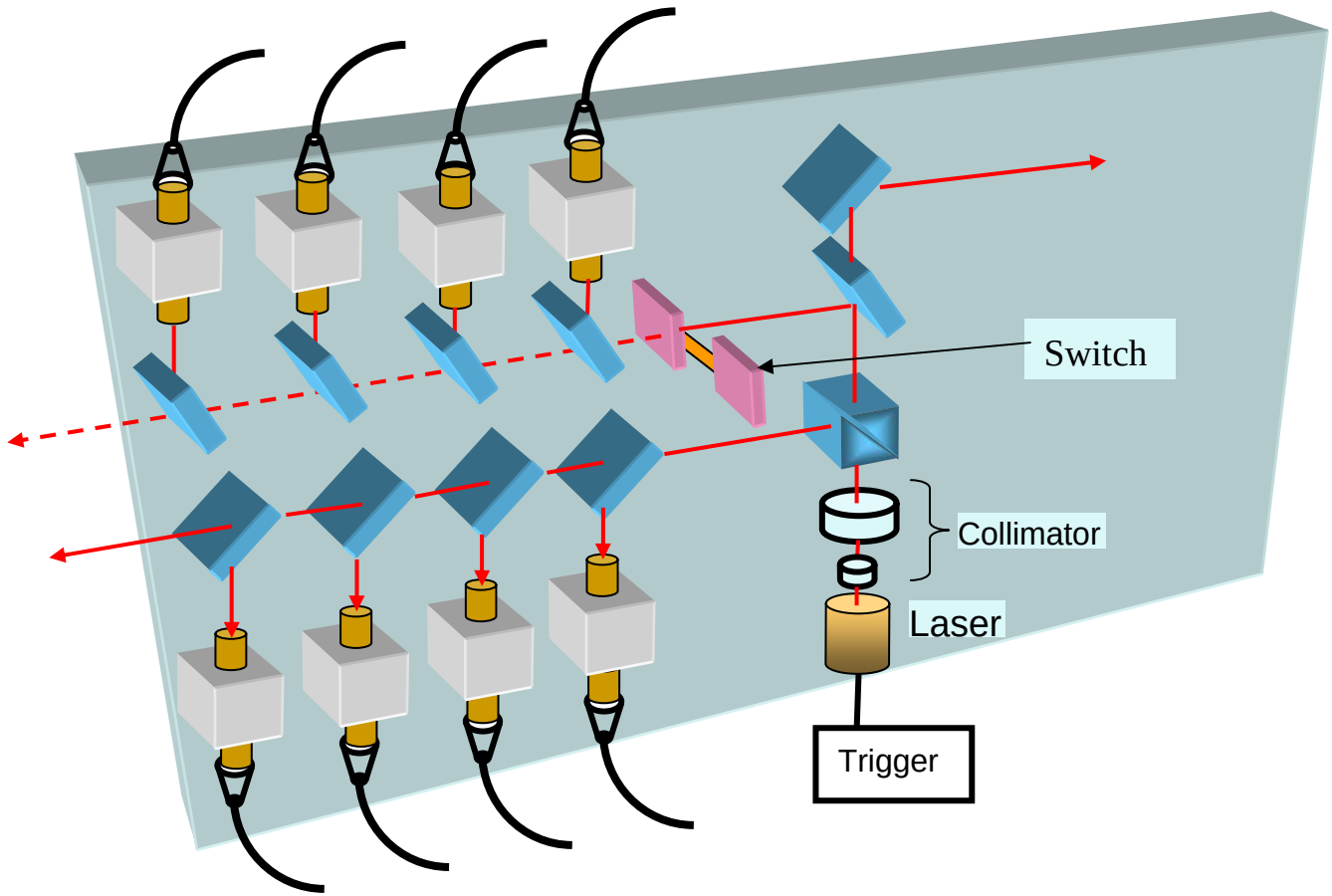
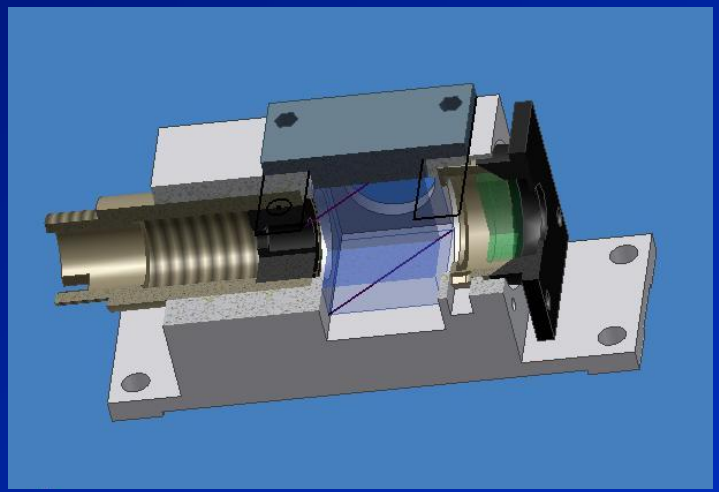


Fig 5. Layout for Option 2. Compared with Option 1, *the Control Room Modules Change, but not those in / on the Tracker*


Switch
Collimator
Laser
Trigger

Optical parts are being supplied to RWTH Aachen and IFCA Santander for incorporation into the CMS sub assemblies.

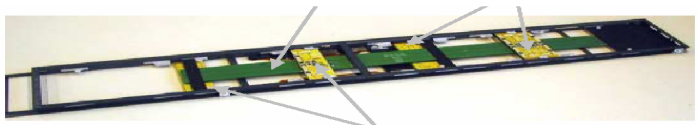


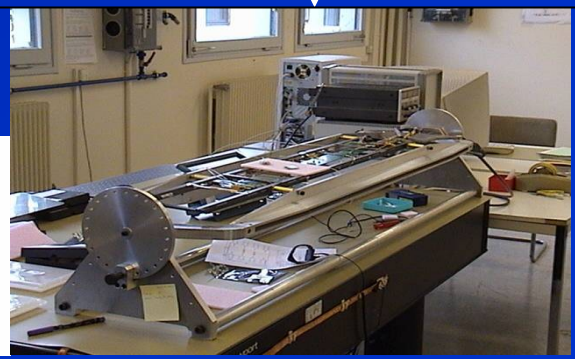
Automatic Test Jigs and Carbon Fiber Frames for Outer and Inner Barrels

Assembly line for TOB Frames, 30 units/day

FERMILAB

CERN





THANK YOU

HIGH TECHNOLOGY

- Man's greatest enterprise at present is high technology …. Technology that is based on science.
- We are heirs to a glorious tradition of human thought.
- It is our heritage as much as it is our right.
- Only those people who control technology based upon science will be masters of their destiny

There are three ways a man can ruin himself:

Gambling Women & Technology

Gambling is the most expensive;
Women are the most pleasurable,
BUT Technology is the most certain way

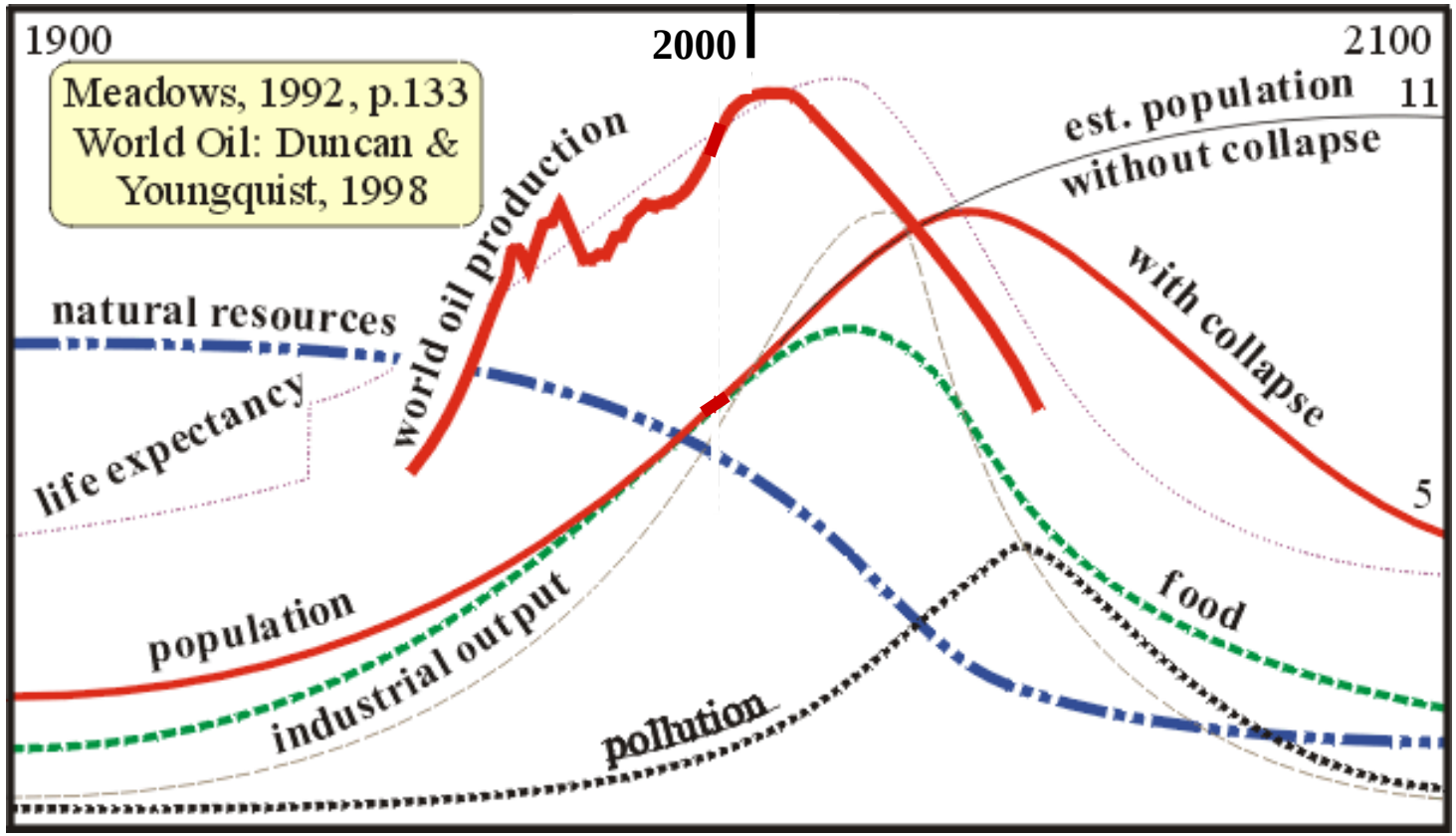
2. Subtraction Method: **The constant value of the noise gives the systematic contribution to the calculations.**

Hence subtract the mean value of the noise from the signal on the pixel before using the CG Method gives greater accuracy. One has to be careful not to subtract more than the constant value , as information of the laser spot may also be lost.

3. Use of Averaged Images: Here the method is applied directly to the expression

Human Overpopulation: Limits to Growth

Systems Crash !



- **Agriculture :** major threats to freshwater.
- **World wide:** ~ 70% of the freshwater is used for agriculture.
- **Pakistan :** Agriculture share (freshwater withdrawal) > 90%.
- **Agriculture :** Responsible for the deteriorating water quality (agrochemicals (fertiliser and pesticides) and soil erosion

- **Cotton:** 2.4% of the arable land , 24% of the world insecticides
- **In Pakistan:** 70% of the imported pesticides are applied on cotton crop. Therefore pesticides use for cotton in relation to area under cultivation is disproportional.

Thank You

ECONOMIC IMPLOSION

Human Economic Development:

Cannot rise indefinitely

Limited by

- **Human Overpopulation**
- **Depletion of Natural Resources**
- **Pollution**

Expect: Hyperinflation, Rationing

- **Energy: If cheap, easy to acquire, pivotal in determining the physical quality of life. USA, Europe, China and Japan will be competing for every tanker of oil … lands with oil? More Iraqs?**

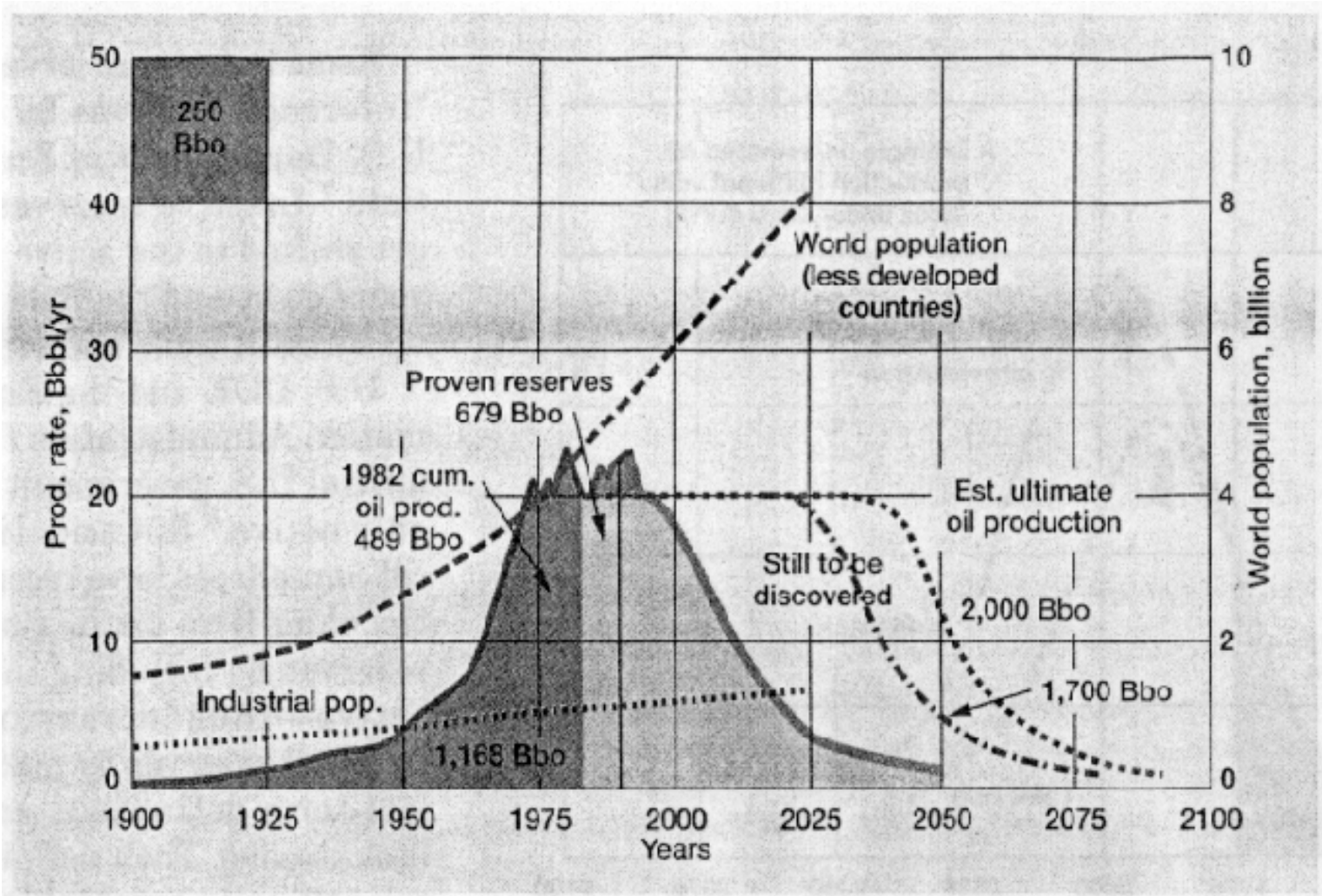
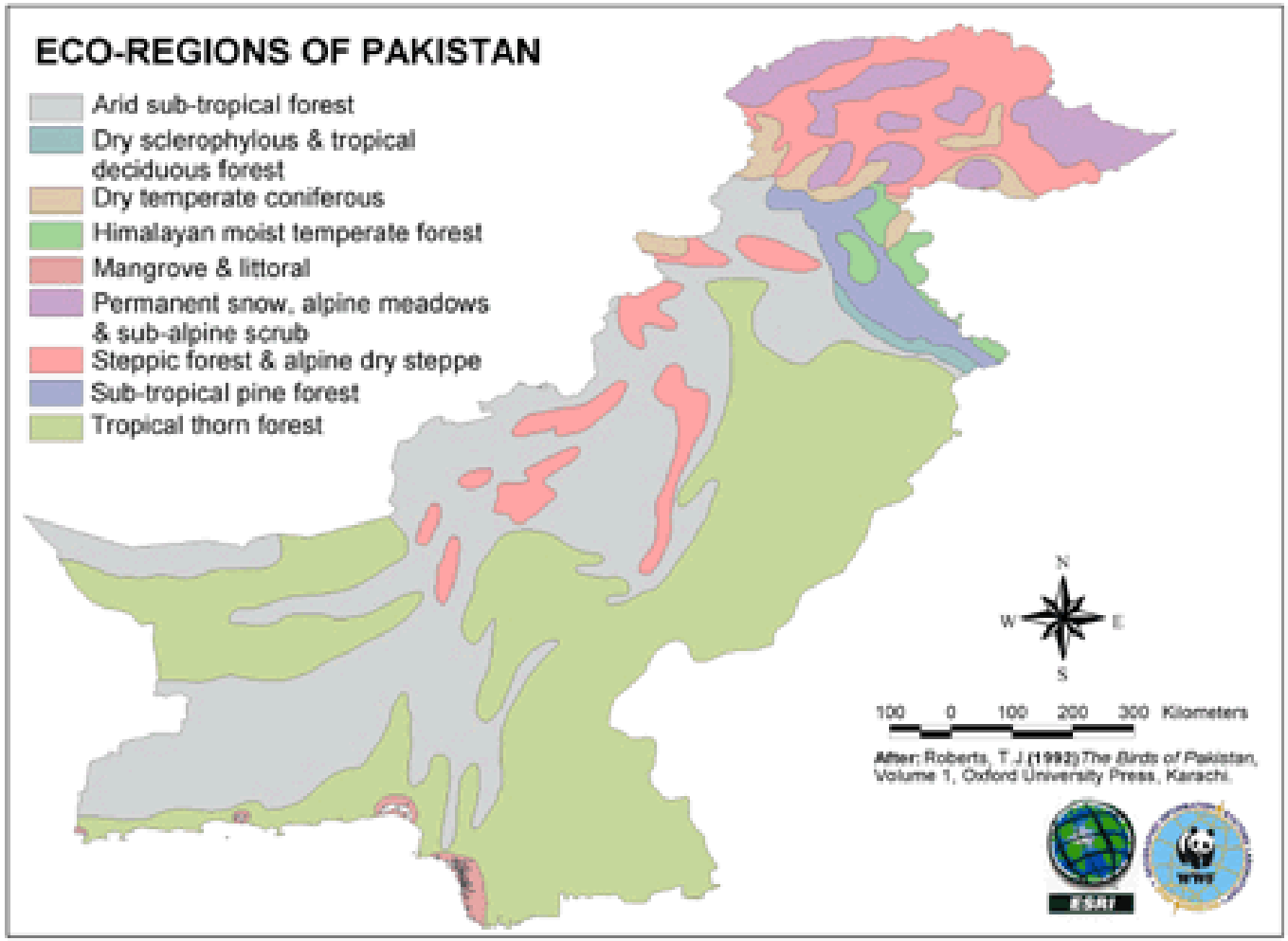


Fig. 4. World crude production history and forecast for two ultimate reserve levels vs. world population increase. Original, Hubbert 1979; revised, Ivanhoe 1986; statistics, D & M 1983; population, NGS 1984.

Pakistan's Ecosystem: one of the 6 great ecosystems of the world is under Severe Threat



Endocrine Disrupting Chemicals:

- **Endocrine glands** > Hormones> guide the development, growth, reproduction, and behaviour of humans and animals **(ex: pituitary, thyroid, and adrenal glands, the female ovaries and male testis).**
- **DDT,** 50 years ago; now no place NOT contaminated by synthetic chemicals.
- **Most EDCs : pesticides** (DDT, Dieldrin, Parathion, Endosulfan, Chlordane, Deltamethrin, Dimethoate, Carbofuran, Propiconazole, Trichlorfan, Metiram). Other EDCs are **industrial chemicals** (Cadmium, Dioxine, Lead, Mercury, Phthalates, and Styrenes).
- **Plastics,** contain Phthalates/ Biphenol A, (strong EDCs). Chlordane is used extensively to control termites and as a broad-spectrum insecticide on a range of agricultural crops

ATOMS DIAGRAM

Atoms have electrons ...

..orbiting a nucleus..

..which is made of protons ..

..and neutrons..

.. which are made of quarks, up quarks(+2/3) & down quarks (-1/3)...

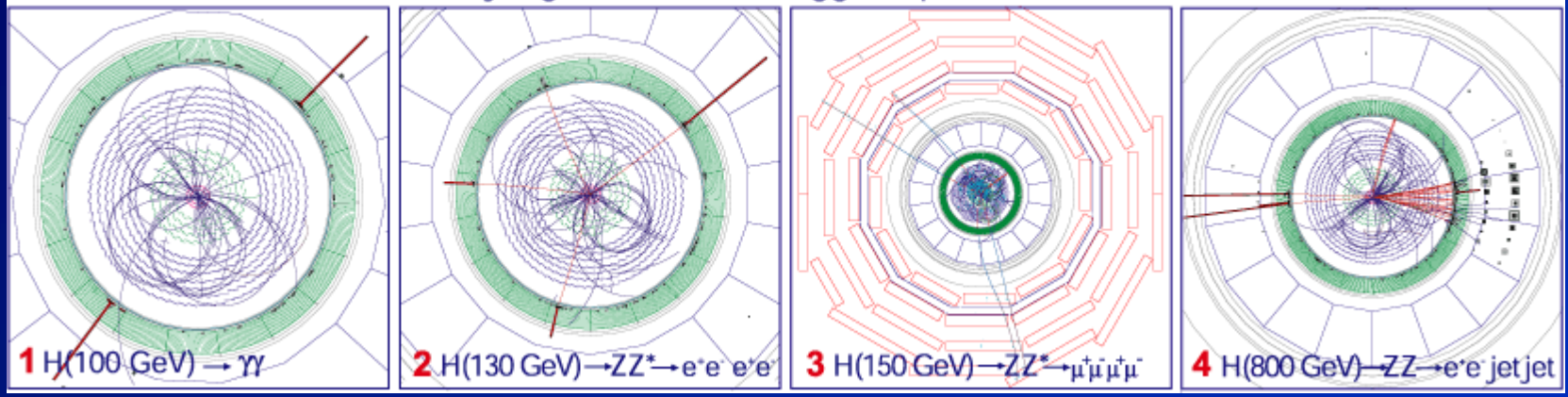
Which are at the current limits of our knowledge

Electron- neutrino:: Vital Role in converting neutrons to protons & vice versa

Weak Force : neutron decay, in the sun H > He,

Strong Force : Holds quarks / protons together

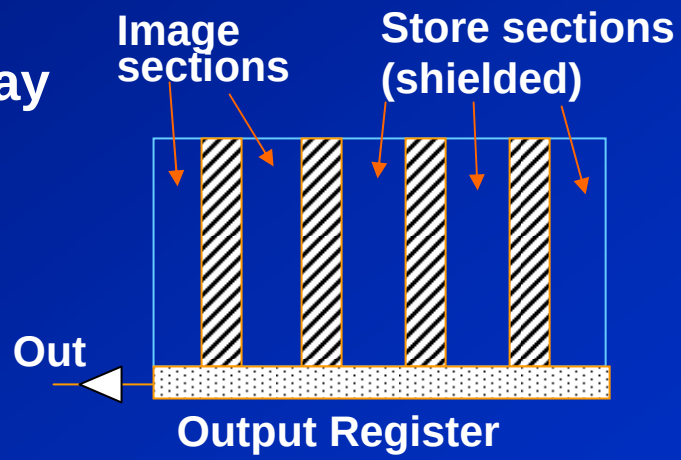
The decay signature of the Higgs depends on its mass:



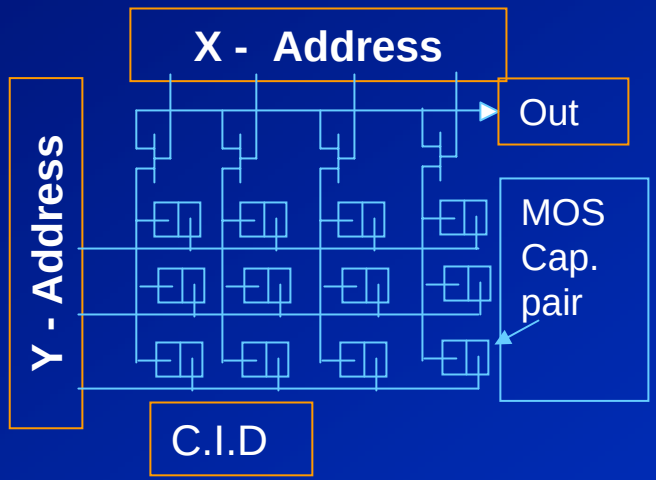
CCD Camera:

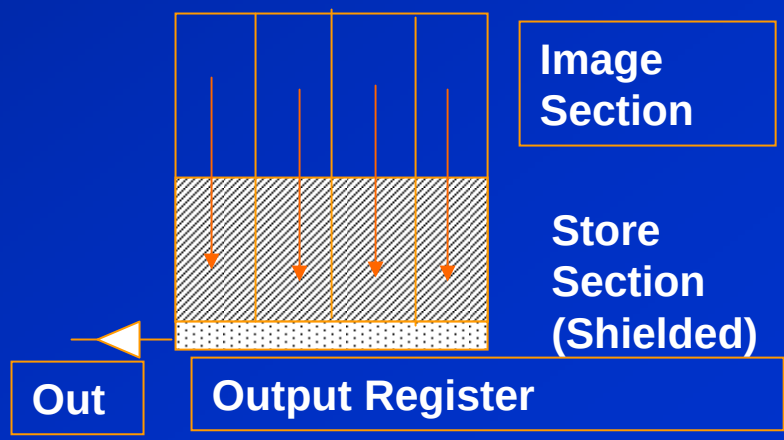
Solid State Sensor; 3 most widely used systems:

1. Interline Transfer Array



2. X-Y Addresed Array





3. Frame Transfer Array

Frame Transfer Types are Best:

- for slow scan,
- electronic exposure control (short exposures) ;
- also give better resolution & sensitivity

MOST DETECTORS ARE BASED AROUND A MAGNET

>> FACILITATES the measurement of the momenta of charged particles.

CMS >< Compact Muon Solenoid ><

Comes Online 2007

Highly efficient muon detection and measurement system;

CMS : Super-conducting Solenoid, 12 m (L) x 6m (ID).

- **FIELD STRENGTH : 4 T ~ 10^5 x the earths mag. field**
- **LARGEST MAGNET of its type ever constructed**
- **ALOWS ALL TRACKING AND CALORIMETRY DEVICES to be placed INSIDE THE COIL of the solenoid - resulting in a compact overall detector.**

High Energy Matter

Natural High Energy Lab. **in the form of Cosmic Showers.. high energy atomic nuclei (protons mostly) from outer space collide with atoms at the top of the atmosphere .. Particles created are called cosmic rays .. include electrons, protons neutrons + many new particles also.**

Near ground > muons (210 x eln. Mass), decay after ~2.2 μsec > electron + eln neutrino, muon neutrino (very light,possibly massless neutral version of the muon)

- **To study high energy particle collisions under controlled conditions >> Labs like CERN**
- **MIMIC the actions of cosmic rays**
- **REACH ENERGIES … common in the universe in its first moments of existence.**

CMS COLLABORATION

36 NATIONS 160 INSTITUTIONS 2008 SC. / ENG.

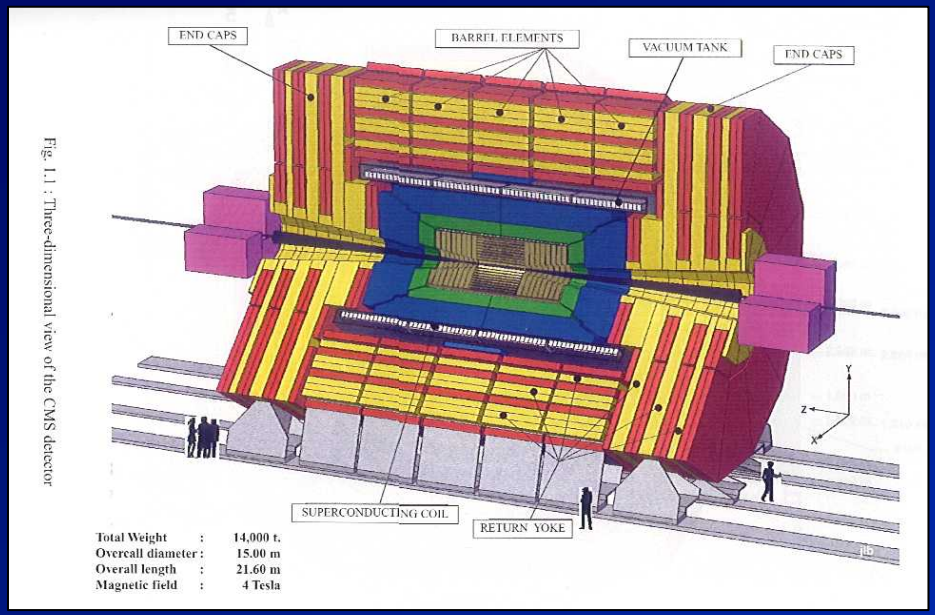
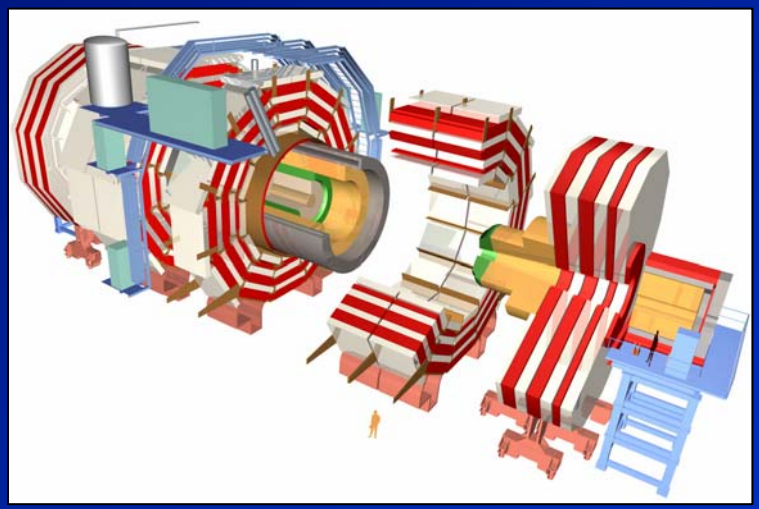


Fig. 1.1 : Three-dimensional view of the CMS detector



PAEC CONTRIBUTION to CERN:

1. **<u>Magnet Feet</u> for CMS (Fabrication only)**
2. **<u>Position Monitoring System</u> for Tracker of CMS (design, fabrication,installation)**