Plans for CMS Upgrades

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Outline

- CMS Plans for Shutdowns
- Technical Proposal

Requirements for the phases of the upgrades: ~2010-2020

- This decade will see the initial operation of the LHC and the increase of energy and luminosity towards the design luminosities.
- Goal of extended running in the second half of the decade to collect ~100s/fb
- Motivation for upgrades during this phase
  - may be based on required performance for higher luminosity, better physics performance, better reliability of operation

2020-2030 – High Lumi LHC

- Continued operation of the LHC beyond a few 100/fb will require substantial modification of detector elements
- The goal is to achieve 3000/fb in phase 2
- Need to be able to integrate ~300/fb-yr
- Will require new tracking detectors for CMS
- Still substantial R/D required for the detectors to be able to operate at these higher luminosities

CMS Upgrade Scope

Agreed at the May 2008 Upgrades Workshop
http://indico.cern.ch/conferenceDisplay.py?confId=28746

2015

2012

2015

2012
/2015

2015

CMS Upgrades ideal scenario

- 2012 Shutdown –
  - Install forward muon systems
- 2015 Shutdown
  - Install new beampipe
  - Install new pixel detector
  - Install HB/HE photo-detectors
  - Install new trigger system
- 2020 Shutdown
  - Install new tracking system
  - Major consolidation/replacement of electronics systems
    - Including potentially ECAL electronics

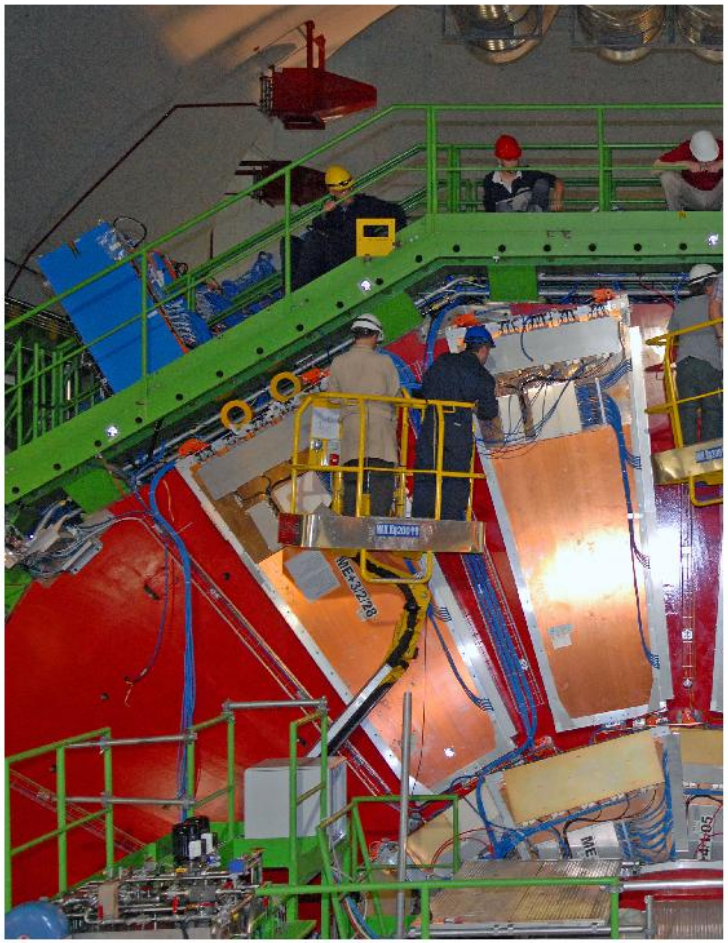
What is required of new detectors for operation up until 2020?

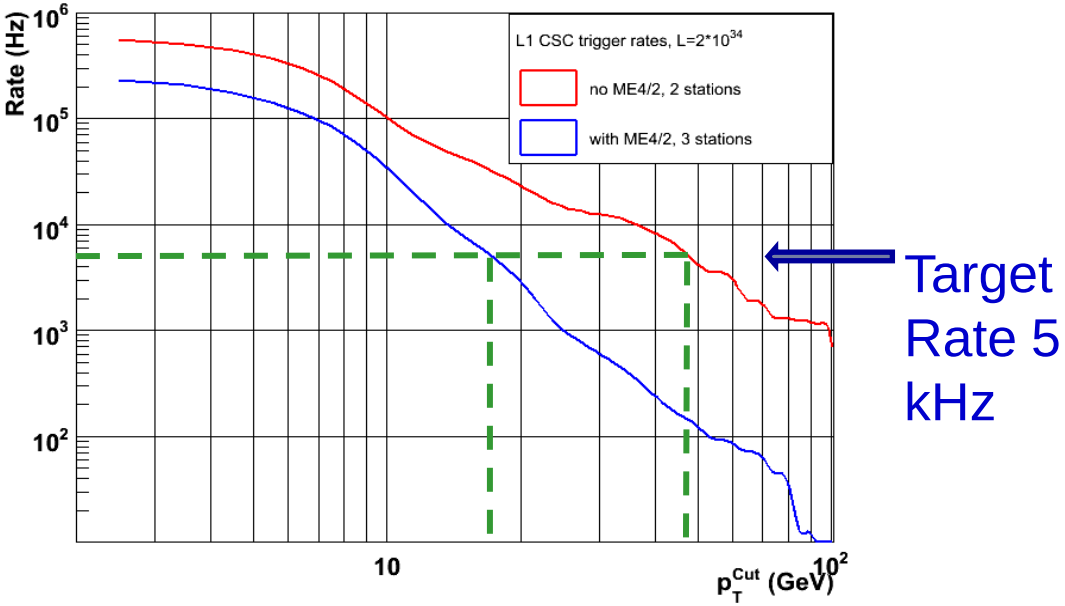
- They should be able to operate with a peak luminosity of up to 2×10^{34}
- They should be able to cope with an integrated luminosity of up to as much as 700/fb
  - Looking at potential increase in luminosity, this now not an issue until late in the decade.
- They should offer increased physics performance

2012: Muons

- CMS design has space for a fourth layer of forward muon chambers – both Cathode Strip Chambers and RPCs
  - They give much better trigger robustness – especially at higher luminosities
  - A fourth layer of shielding is also for-seen (YE4)
- These are built to the same design as those already installed
- Technically ready to produce chambers
- Imminent Steps
  - Prepare bat 904 for CSC Production, and produce first chambers this year
  - EDR this summer
    - Plan for RPC Production
    - Installation plan for CSC/RPC/YE4

Phase 1 : Muons ME4/2 upgrade motivation

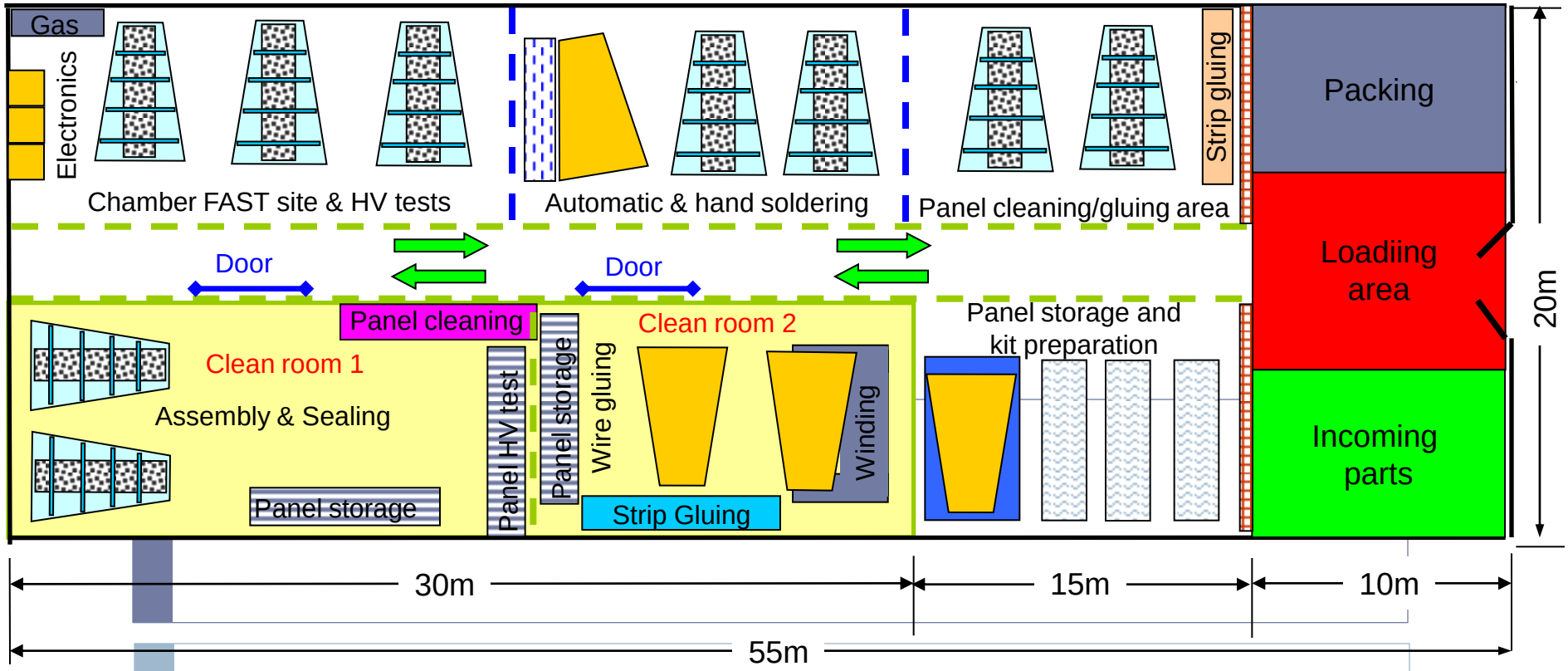




- Compare 3/4 vs. 2/3 stations:
  - (Triggering on *n* out of *n* stations is inefficient and uncertain)
- Recent simulation with & without the ME4/2 upgrade:
  - The high-luminosity Level 1 trigger threshold is reduced from 48 → 18 GeV/c

CSC Factory Production Site at CERN

Floor plan layout at Bldg 904 (Draft)



Based on experience of ME4/2 prototype production the proposed area at 904 of ~ 1000 m2 should be enough to place a factory production and FAST test site. For the completed chambers we need additional storage area of ~ 250m^2.

2nd Shutdown: Pixels

- Well developed plan for a new 4 Barrel layer, 3 end disk low mass pixel detector
  - Fall forward scenario – gives a way to proceed at full speed with the current mature design while giving aggressive options
- Issues for Pixel replacement
  - Radiation hardness, reparability of the inner layer(s)
  - Buffer sizes (data loss at higher luminosities)
  - B tagging capabilities

New 4 Layer pixel detector

- **New Layout: 4 layers and 3 disk/side**

- Baseline Option: 4 layers/3 disks new 250 nm PSI46dig ROC

- PSI46dig ROC: reduce data losses at high luminosity, more robust digital readout, protection mechanism against large clusters induced by beam background

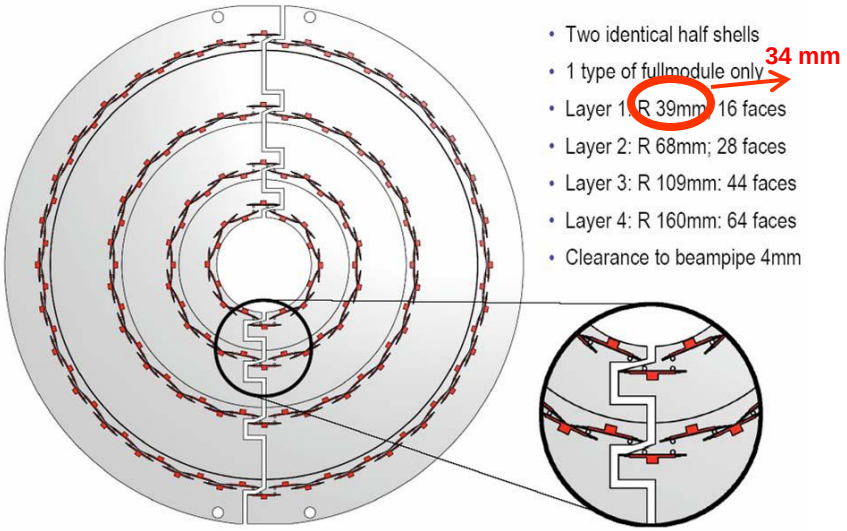
- Inner layers and inner disks: designed for easy and fast replacement.

- Inner layer: closer to IR (from 44 mm present to possibly 39-34 mm maximizing benefits beam pipe reduction to 25 mm)

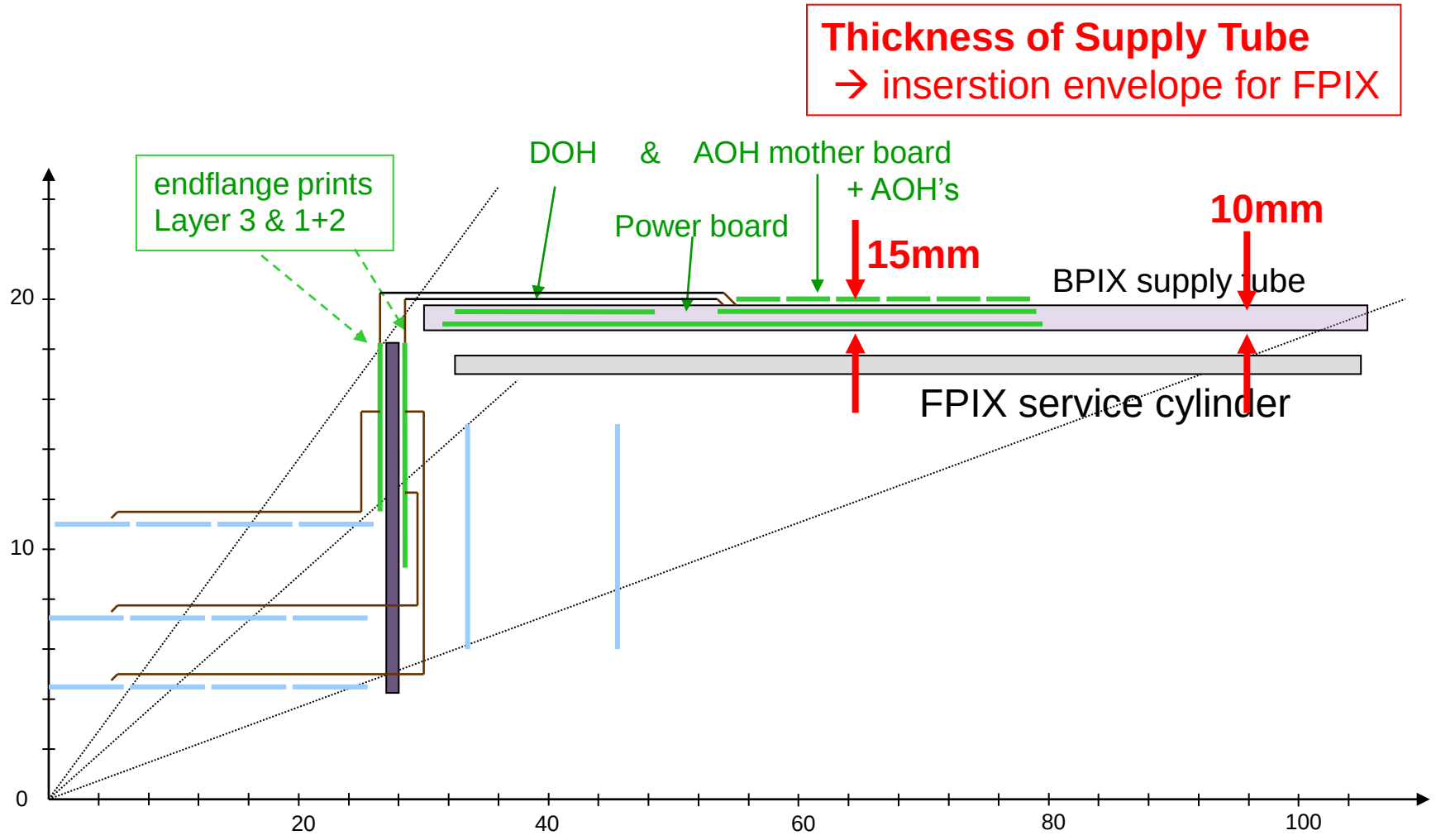
- Outer layer and disks: closer to Tracker Inner Barrel (160 mm w.r.t 106 mm present detector)

- Material budget: aim for major reduction (at least 60% reduction)

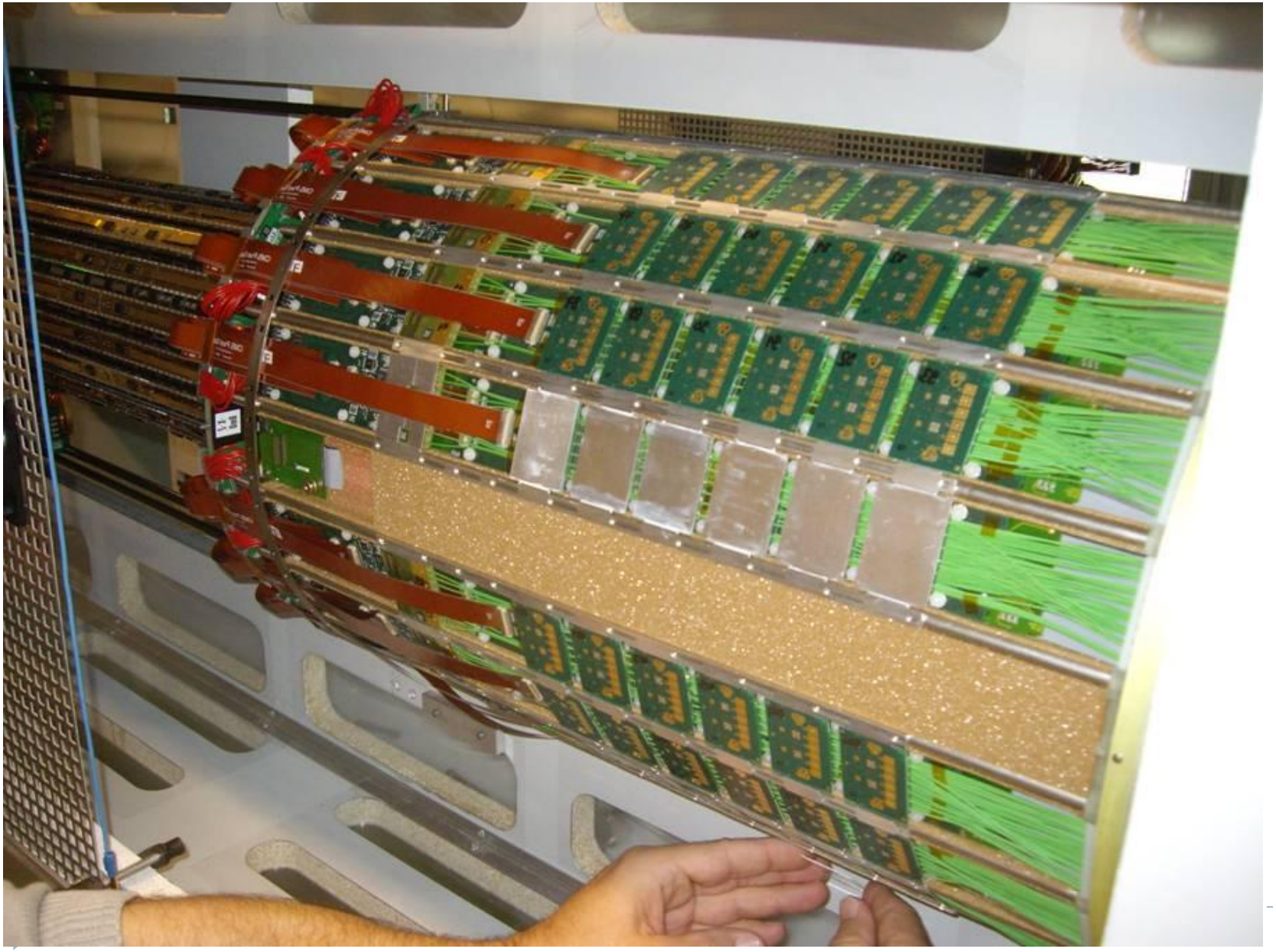
- Fall forward line: Two inner layers/inner disks better hit resolution and radiation tolerance
  New ROC chip optimized for lower threshold possibly able to digest higher rate,
  50% pixel area (75µm x 100 µm or smaller) a thinner sensors



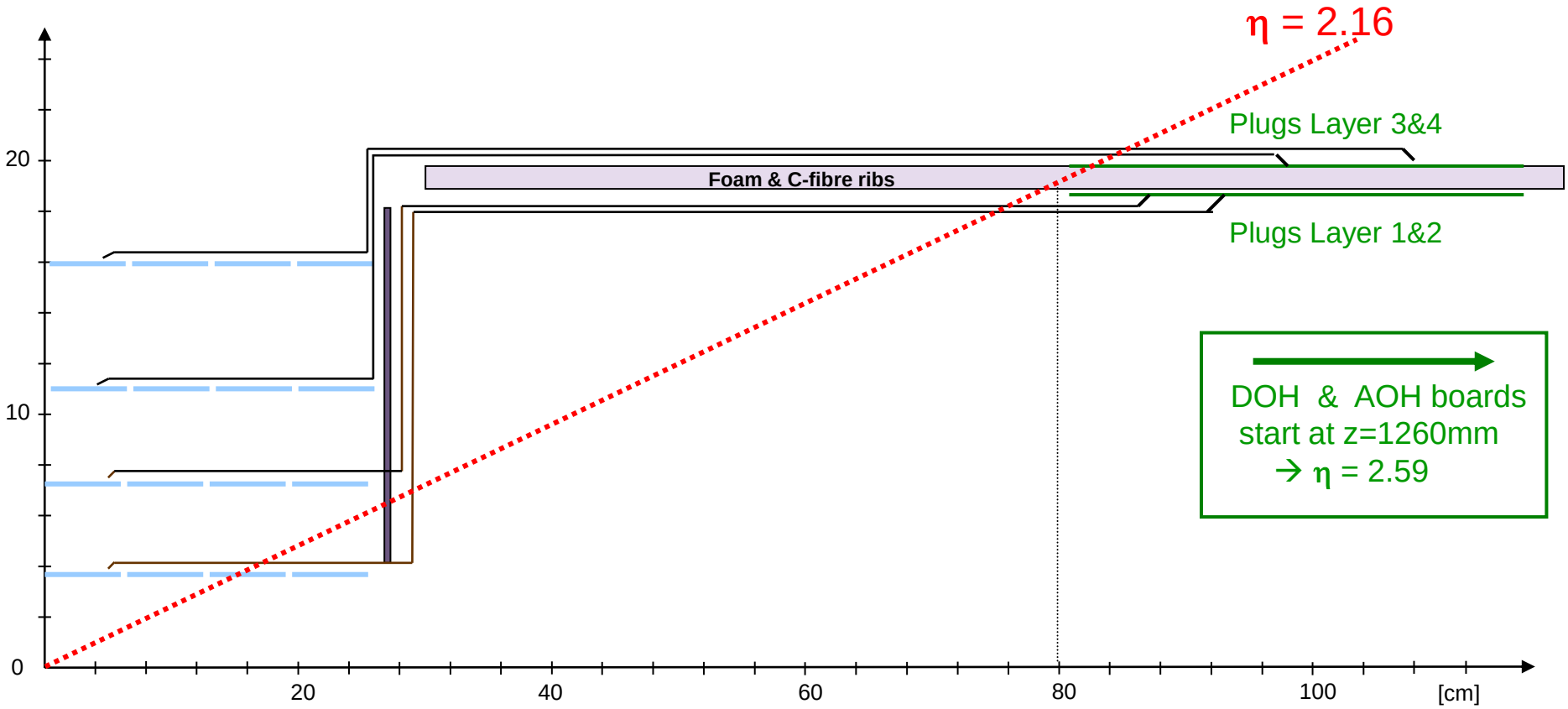
Current Pixel System with Supply Tubes / Cylinders



BPIX & Supply Tube with AOH, DOH, PCBs & Fibres



Weight of 2015 Phase 1 Pixel System (4 layers)



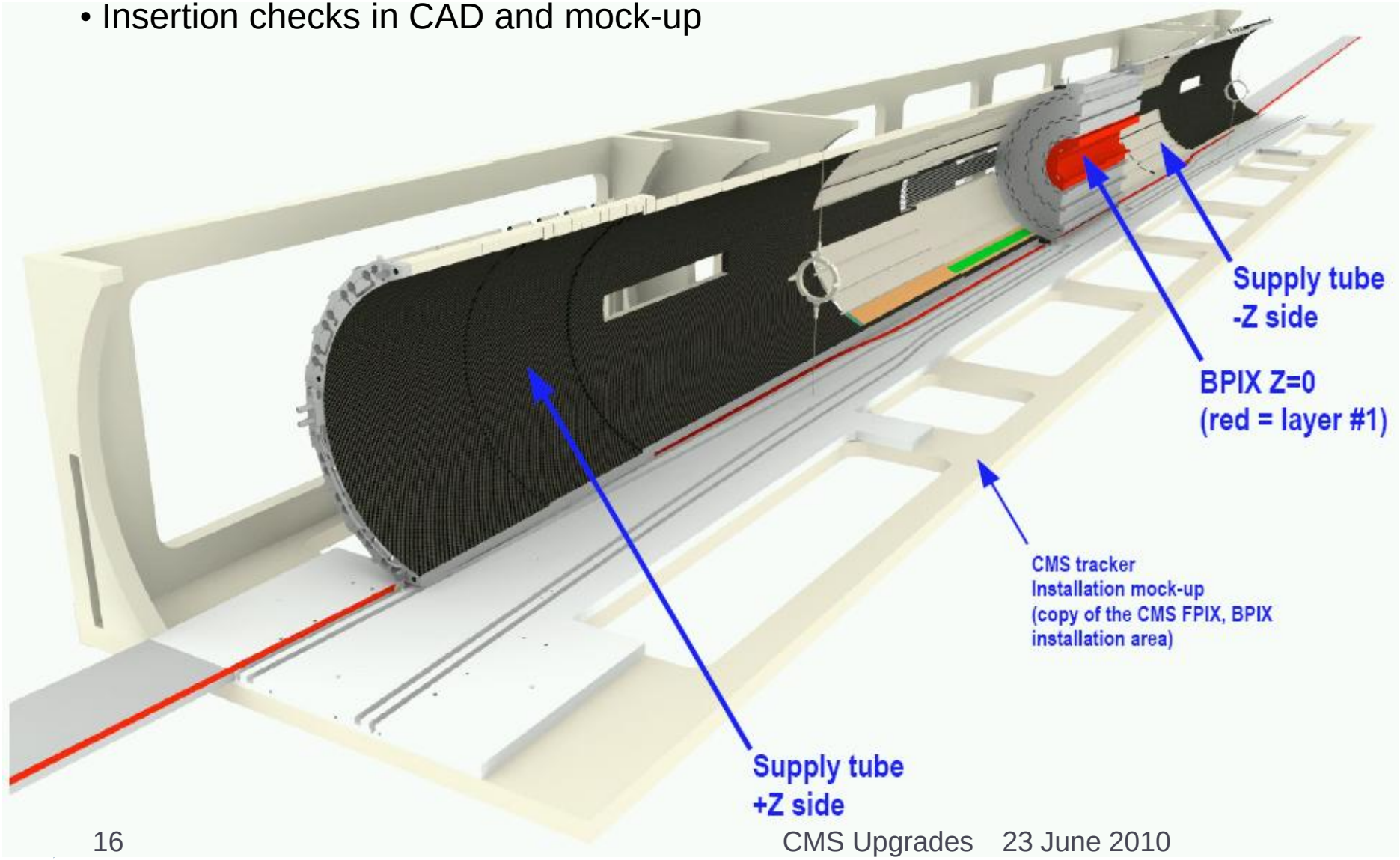
Total weight of 2014 4 Layer BPIX within η<2.16 : 6454 g ~ 6.5 Kg

2 Barrels & 4 Supply Tube Sections & CO_2 & Cables

Ratio (3 Layers 2008 / 4 layers 2015) ~ 2.62

Overview of 2015 4 Layer BPIX System

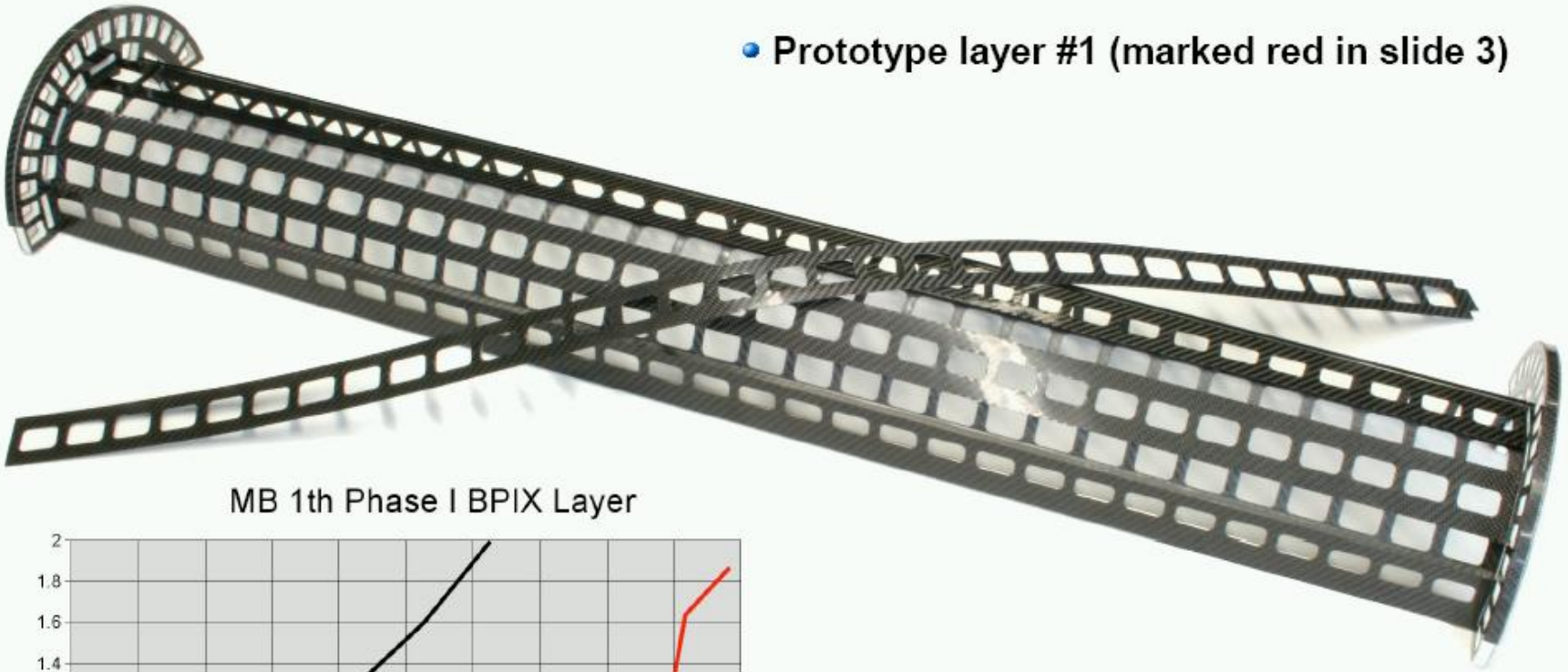
- Insertion checks in CAD and mock-up



1 Layer of new Ultra Light Mechnaics

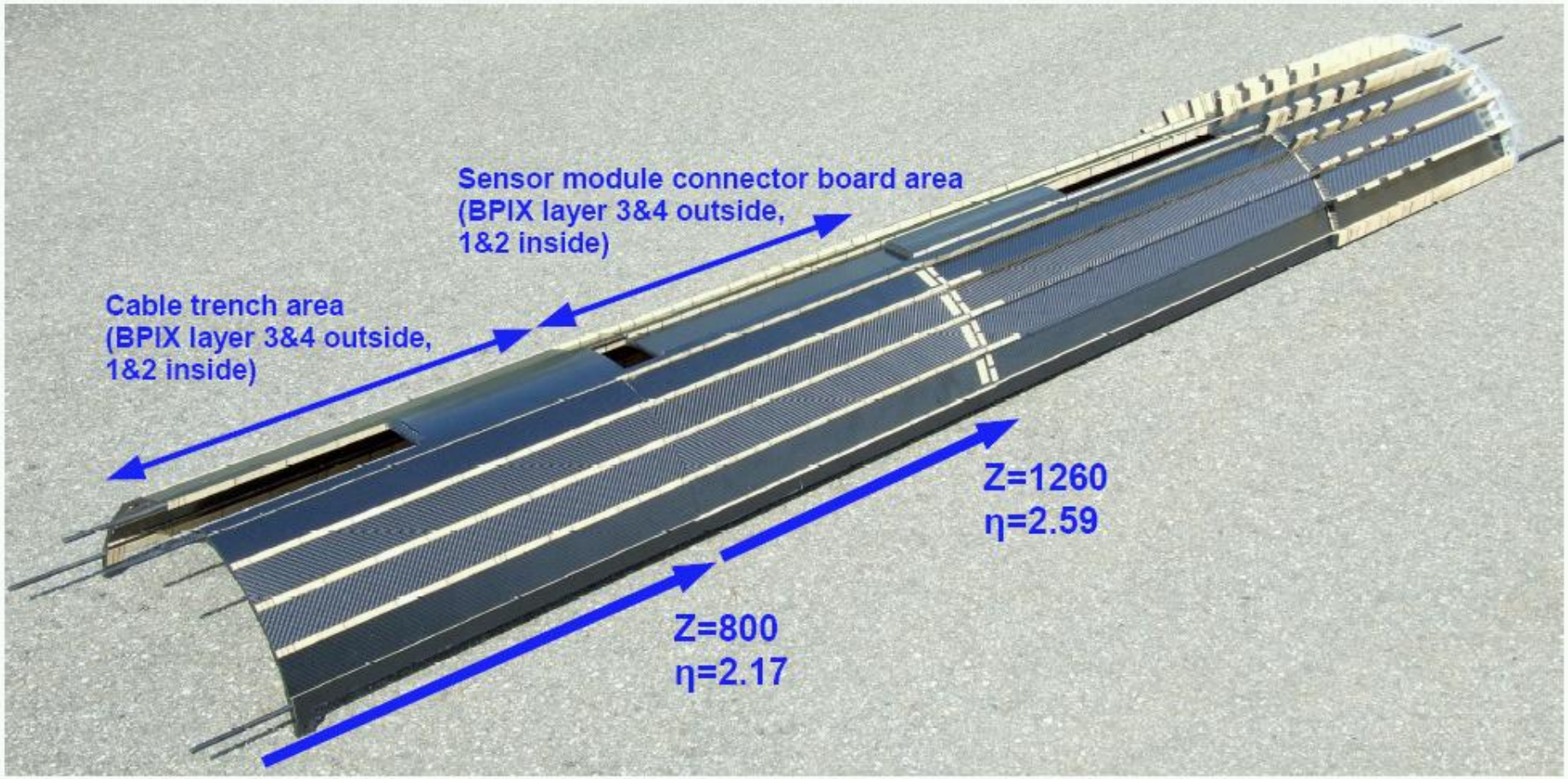
- CO_2 cooling circuit (50μm wall thickness tubes) pressure tested to 100 bar

- Prototype layer #1 (marked red in slide 3)



- New material budget is 30% off current BPIX

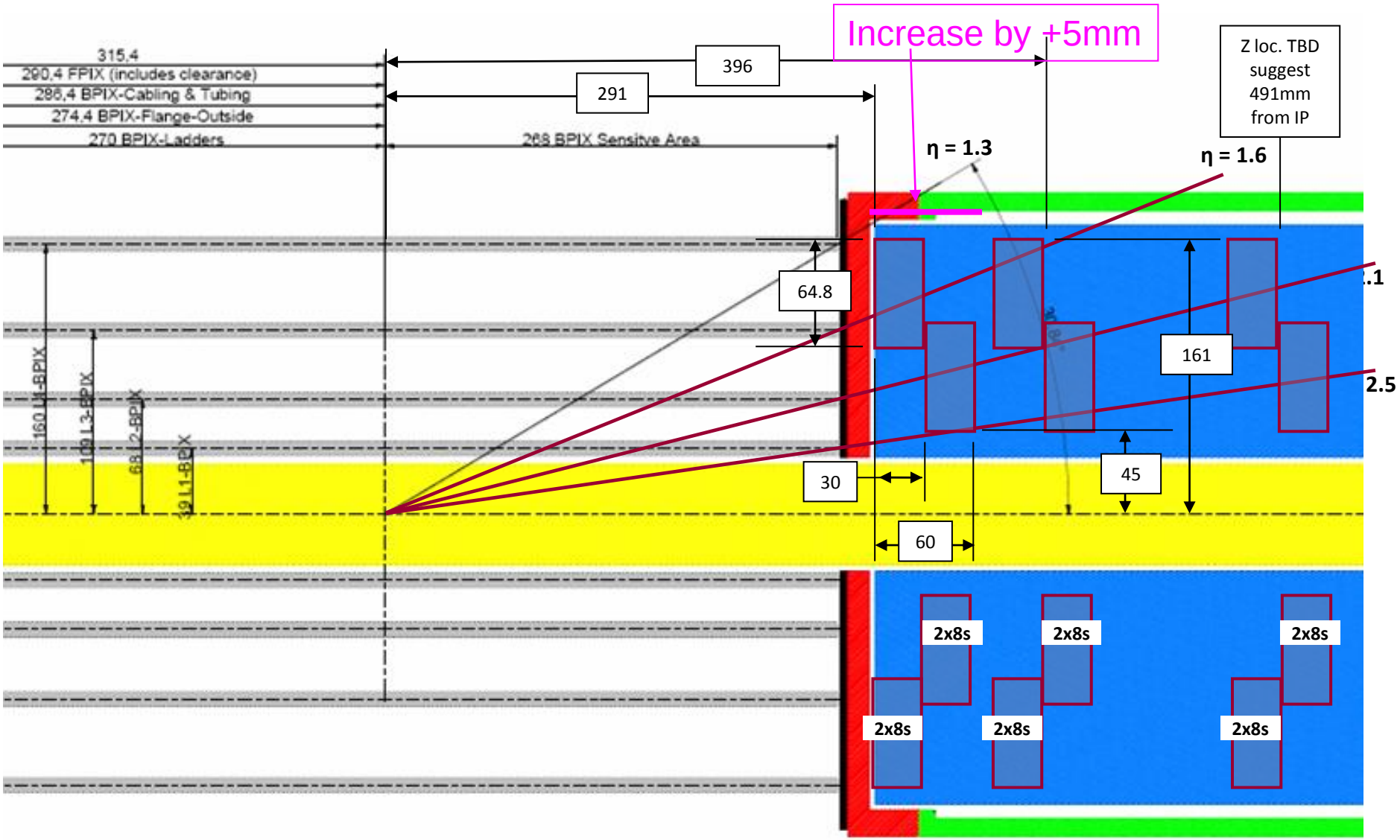
New BPIX Supply Tube



- Note: Some minor carbon fiber parts not yet glued.

- **CO2 cooling loops are to be inserted**

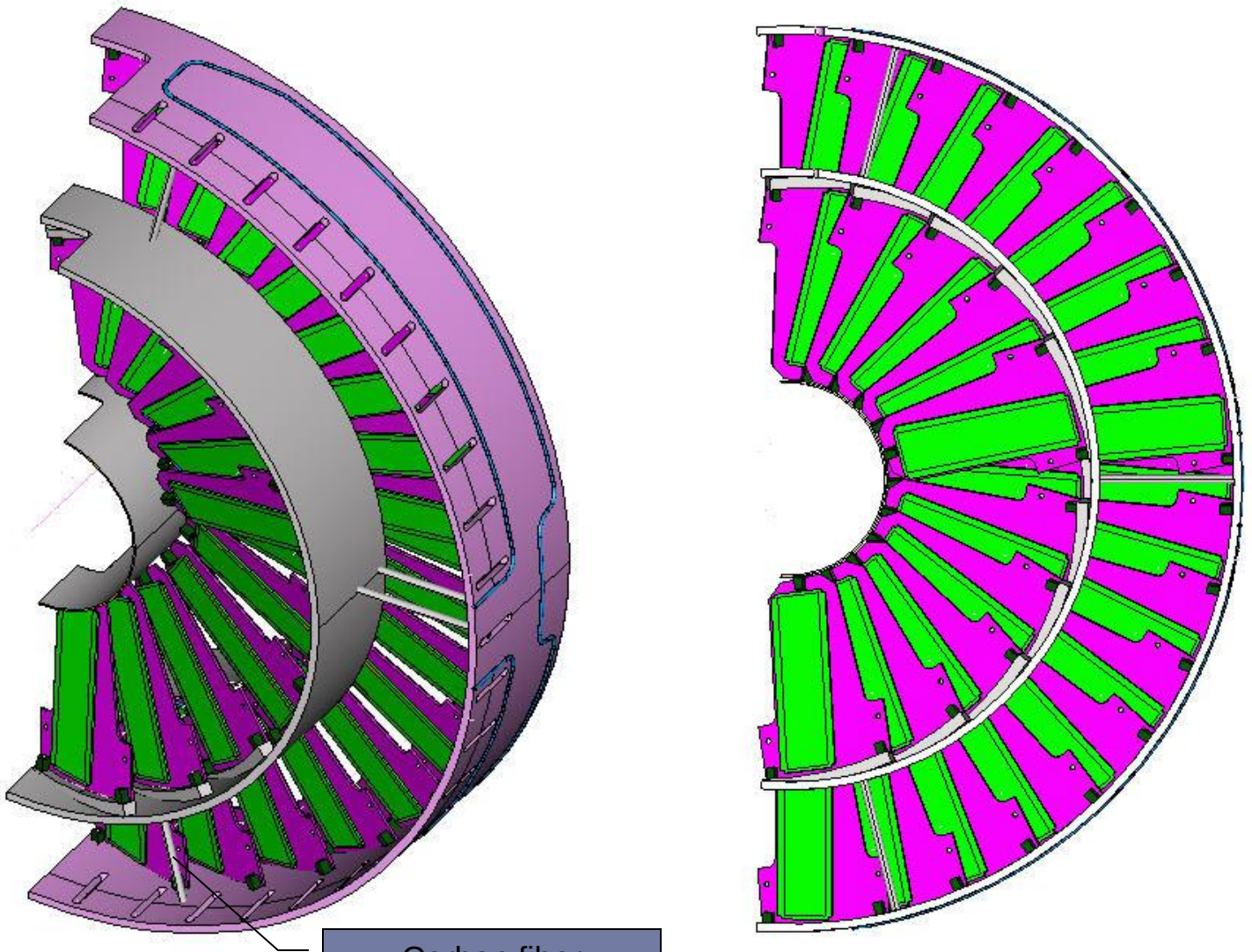
BPIX / FPIX Envelope Definition for 4 Hit Pixel System



All Identical disks (1st and 2nd disks in locations to maximize 4-hit eta coverage)

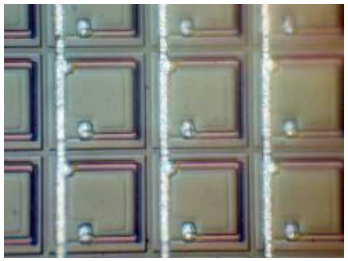
6 disks = (6x68) outer + (6x44) inner = 672 2x8 modules (10752 ROCs)

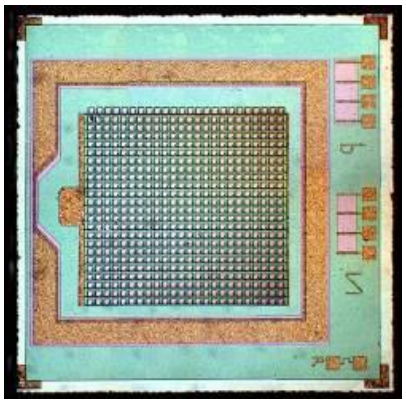
The Half Disk (to be completed)

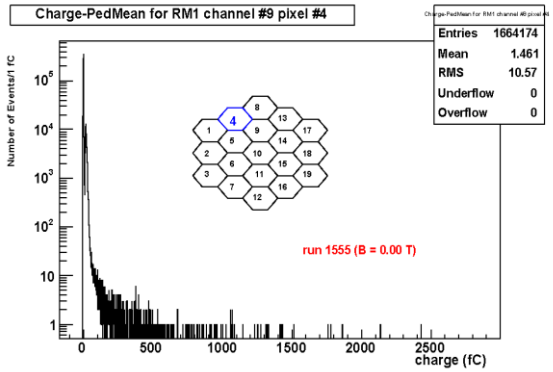


2015:New Photodetectors for Hadron Calorimeter-SiPMs

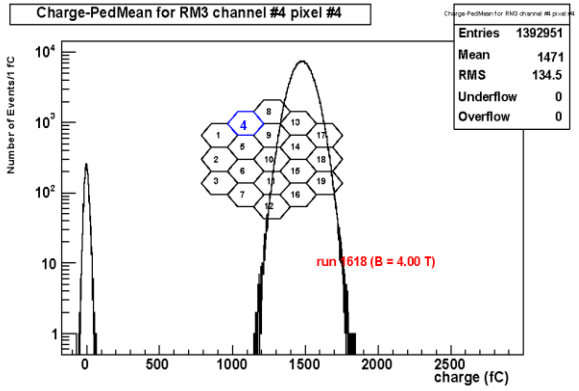
- Array of avalanche photo diodes ("digital" photon detection)
  - Array can be 0.5x0.5 up to 5.0x5.0 mm^2
  - Pixel size can be 10 up to 100μ
- All APDs connect to a single output
  - Signal = sum of all cells
- Advantages over HPDs:
  - 28% QE (x2 higher) and 10^6 gain (x500 higher)
  - More light (40 pe/GeV), less photostatistics broadening
  - Very high gain can be used to give timing shaping/filtering





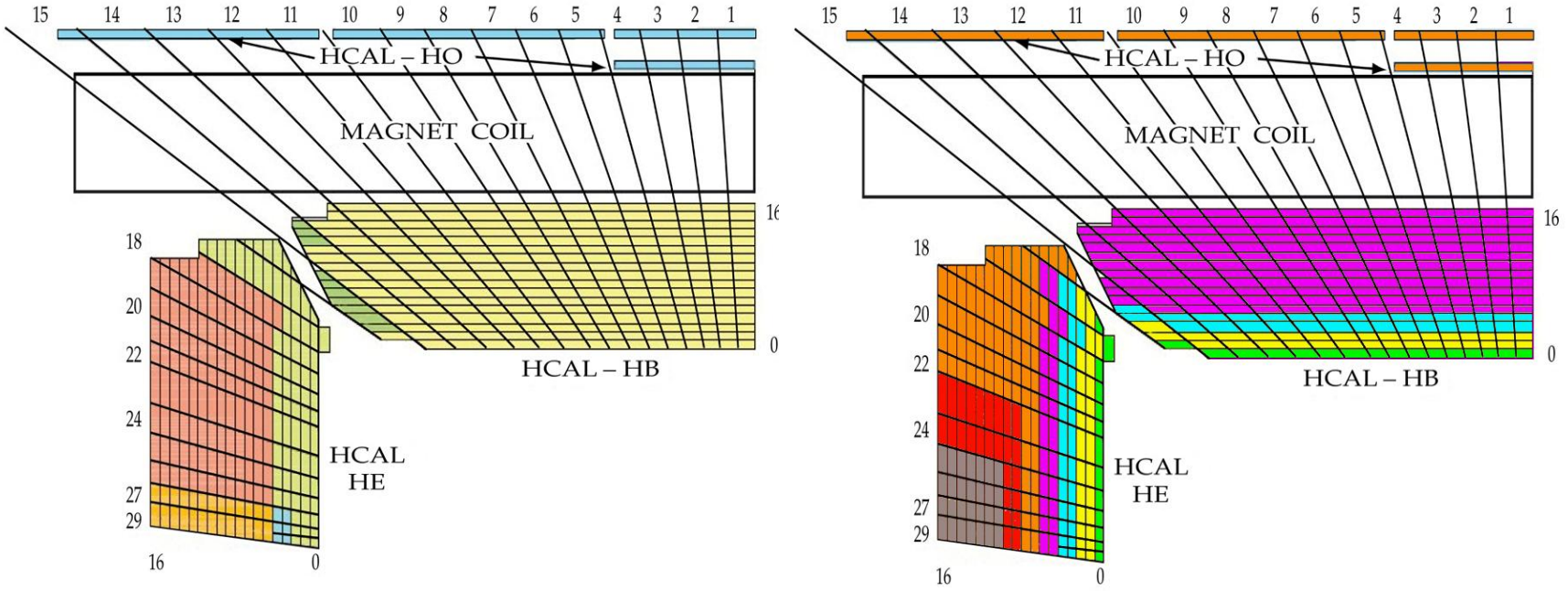


HPD



SiPM

New Photodetectors allow finer segmentation of readout in depth



New segmentation – more robust against damage to inner scintillator layers

2nd shutdown: Trigger

- Issues for Trigger upgrade
  - New technology for trigger systems
    - More common components, easier to maintain
  - Finer granularity processing – better performance
  - Key Issue: How to smoothly integrate a new trigger into a running experiment
    - Parallel operation
    - Slice tests of new detector back/ends and trigger system

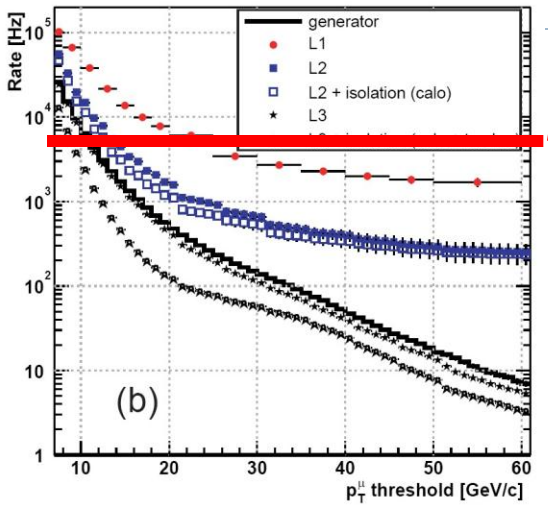
High Luminosity running

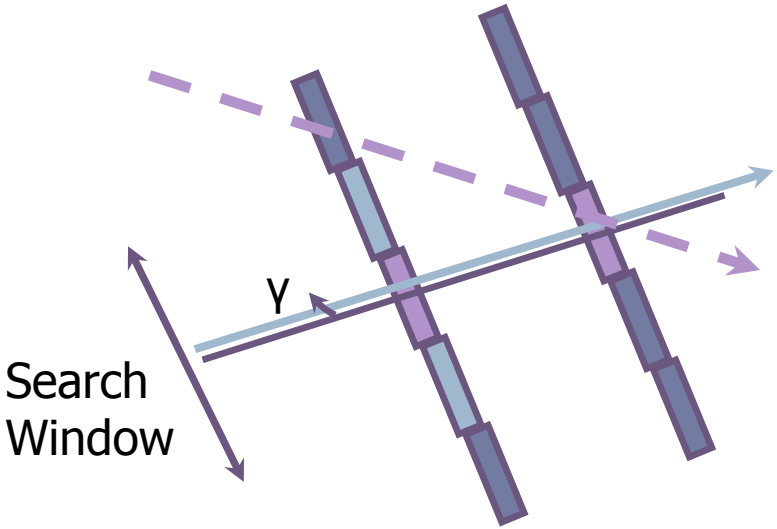
- High Luminosity phase will come sometime around 2020
  - The machine still has a number of options
  - We should be prepared for 25 or 50 ns operation
    - This does have significant implications for the performance requirements, but we have to be prepared for this
  - The peak luminosity is likely to be slightly lower than we had thought 2 years ago
  - Replacement of the full tracker is the main upgrade item
    - R/D for this needs to ramp up in the coming years to meet these timescales
    - Want the best physics performance from a new tracking device in this challenging environment
      - Look at reducing material

Tracking in L1 Trigger

Level 1 Trigger has no discrimination for P_T > ~ 20 GeV/c

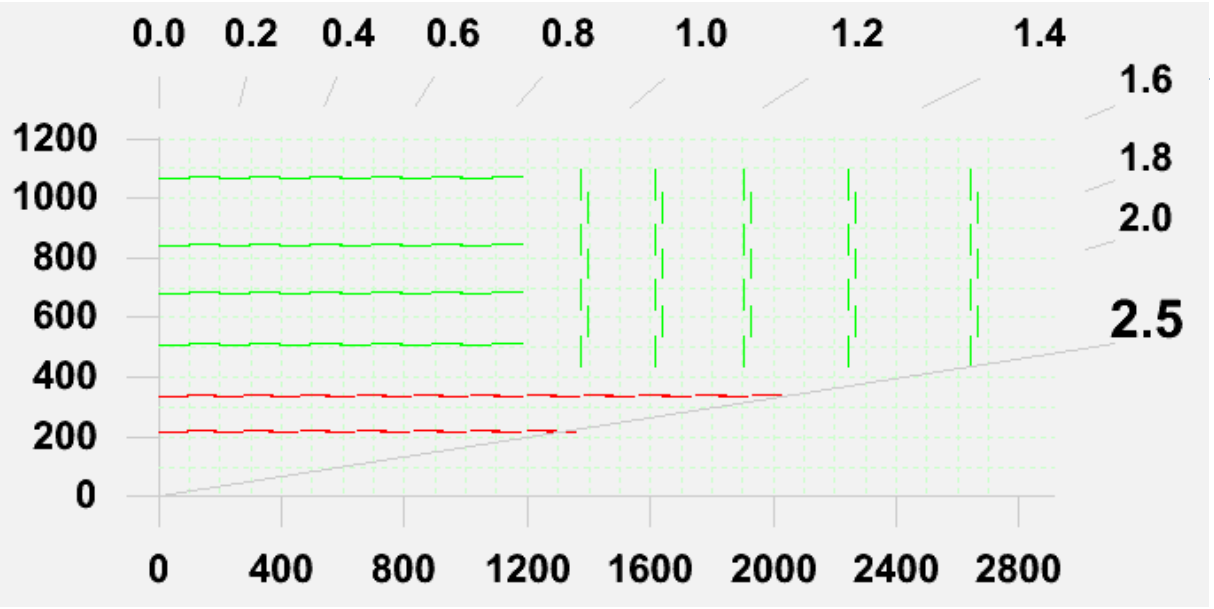
- One of the key issues for CMS is the requirement to include some element of tracking in the Level 1 Trigger
  - One example: There may not be enough rejection power using the muon and calorimeter triggers to handle the higher luminosity conditions at SLHC
- Topic requiring substantial R&D
  - "Stacked" layers which can measure p_T of track segments locally
    - Two layers about 1mm apart that could communicate
  - Cluster width may also be a handle

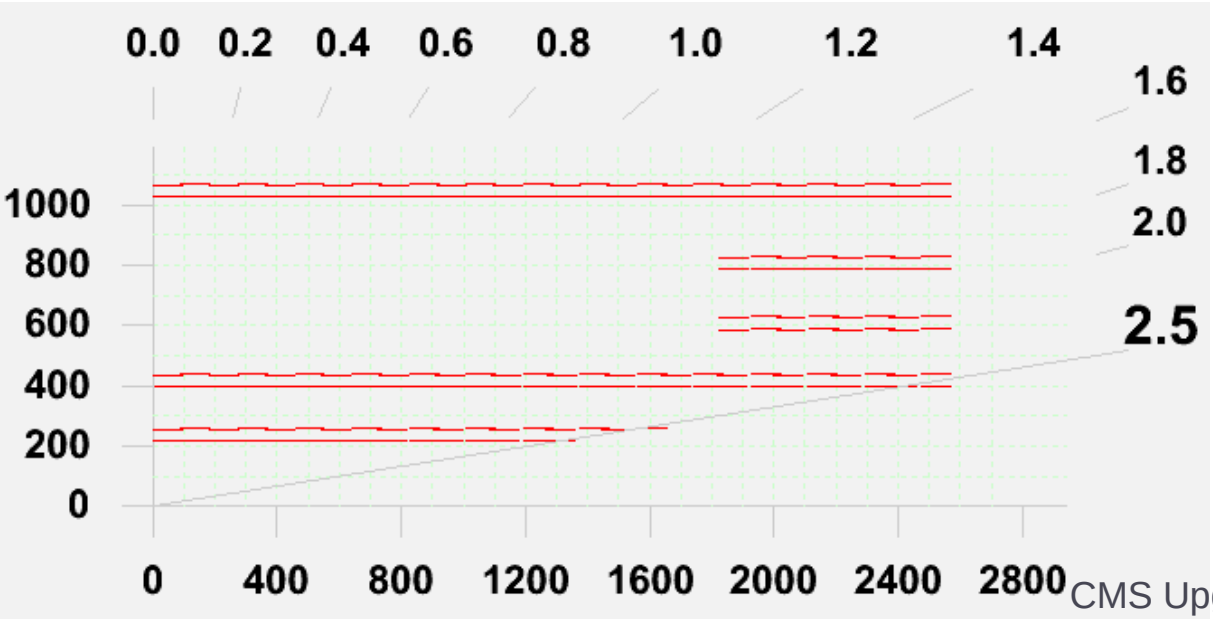




High momentum tracks are straighter so pixels line up

2020:Studies of new tracker layouts

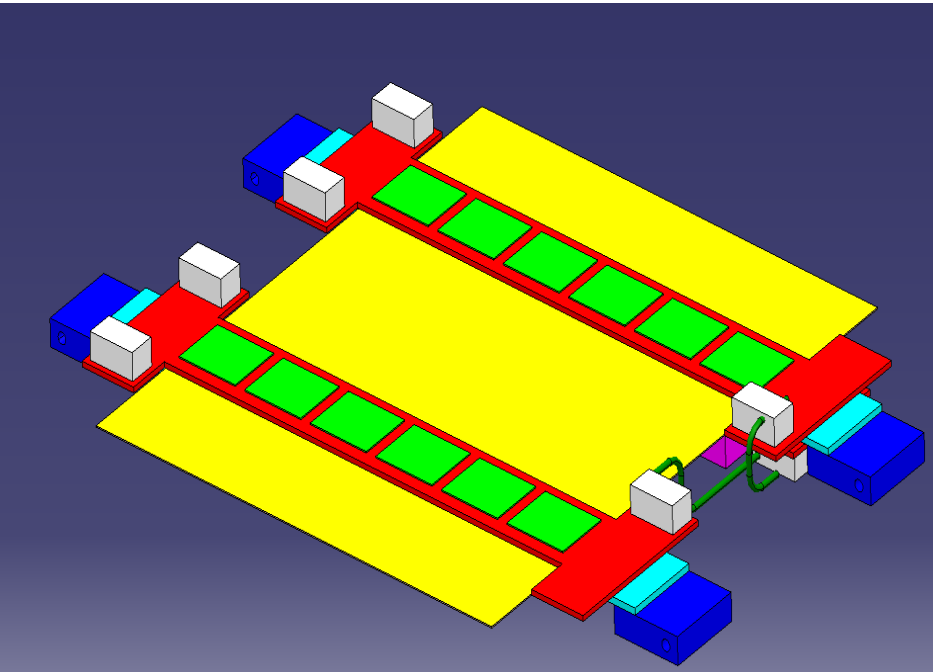


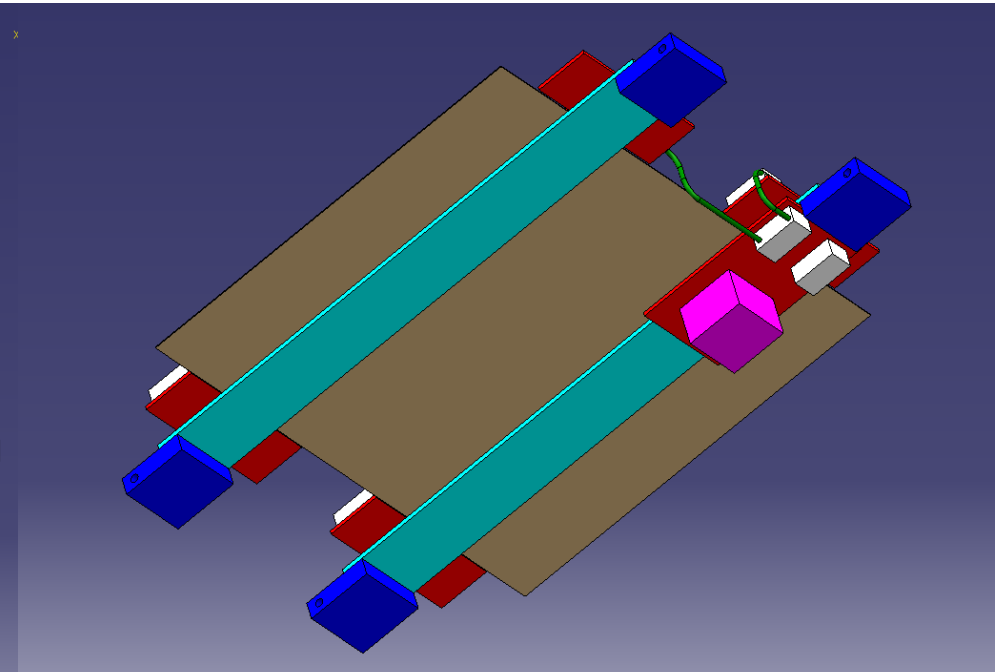


- Studying several potential layouts for a new outer tracker
- Want to increase granularity as well as minimize material in future tracker
- New Tracker must contribute to the Level 1 Trigger
- Need to understand how many triggering layers (in red at left), and where they need to be located in order to provide adequate triggering capability

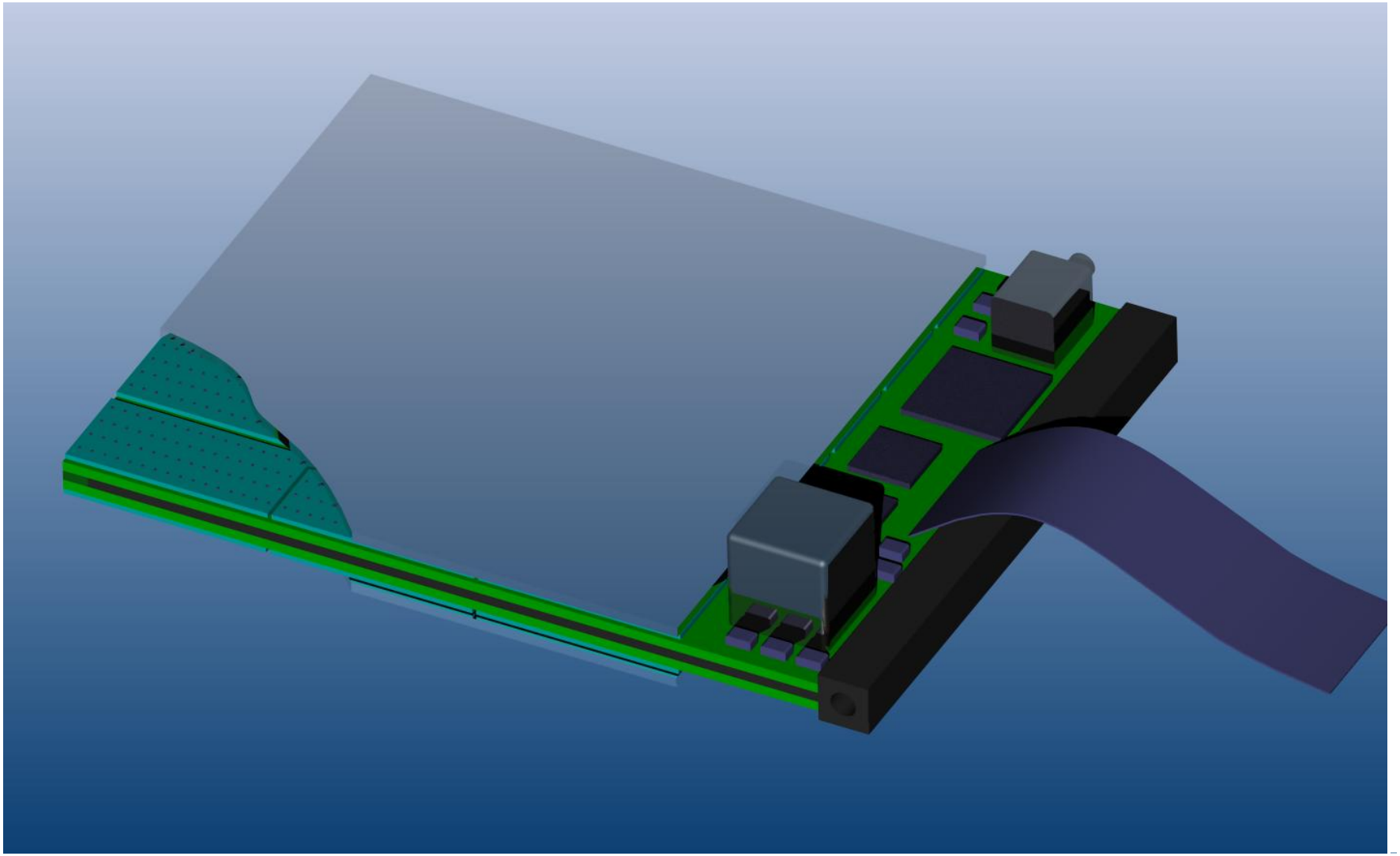
Strip readout layers

- Prototype readout chip going to submission
  - Binary chip, non-sparsified readout
  - Optimized for low-power, simple and robust system (<0.5 mW / channel)
  - Designed for 25 mm ÷ 50 mm long strips
- First module concept developed…
  - Generous volumes reserved for connectors, services, and auxiliary electronics





Example concept of a pixelated P_T module



Technical Proposal

- We are committed to producing a Technical Proposal in September 2010.
- Submit to LHCC for approval
- explains our rationale for taking decisions on potential upgrades

Conclusions

- Firm planning for the upgrades in this decade
  - Technical Proposal being prepared now
- R/D for new tracking systems required in the next decade well underway