

Plans for CMS Upgrades

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Outline

- ▶ CMS Plans for Shutdowns in this decade
- ▶ 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 $\sim 100\text{s}/\text{fb}$
- ▶ 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 $\sim 300/\text{fb-yr}$
- ▶ 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

2015

2012

2015

2012
/2015

2015

CMS Upgrades ideal scenario

- ▶ 2012 Shutdown
 - ▶ Begin Installing forward muon systems
 - ▶ HO SiPMs (Hadronic Calorimeter Tail Catcher)
 - ▶ HF PMTs (Forward Hadron Calorimeter eta 3-5)
 - ▶ Pixel Luminosity Telescope
- ▶ 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
 - ▶ ECAL Endcaps (subject of a task force)
 - ▶ DAQ system upgrade

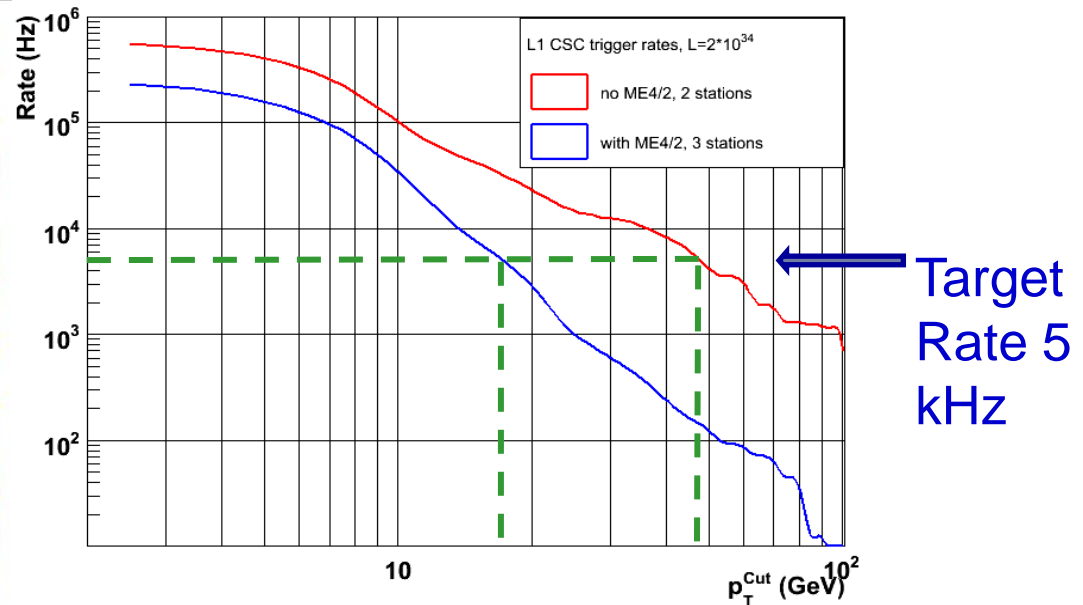
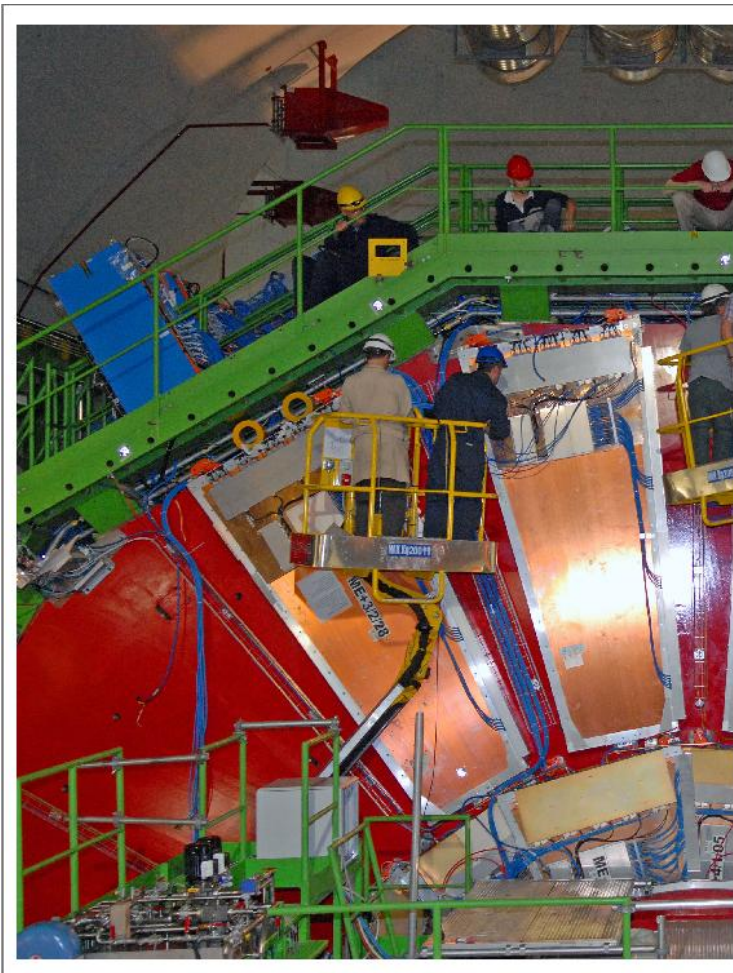
What is required of new detectors for operation up until 2020?

- ▶ 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.
 - ▶ Be able to cope with whatever scenario develops before the long shutdown to replace triplets/tracking detectors
- ▶ 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
 - ▶ Funding is not yet fully secured
- ▶ 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

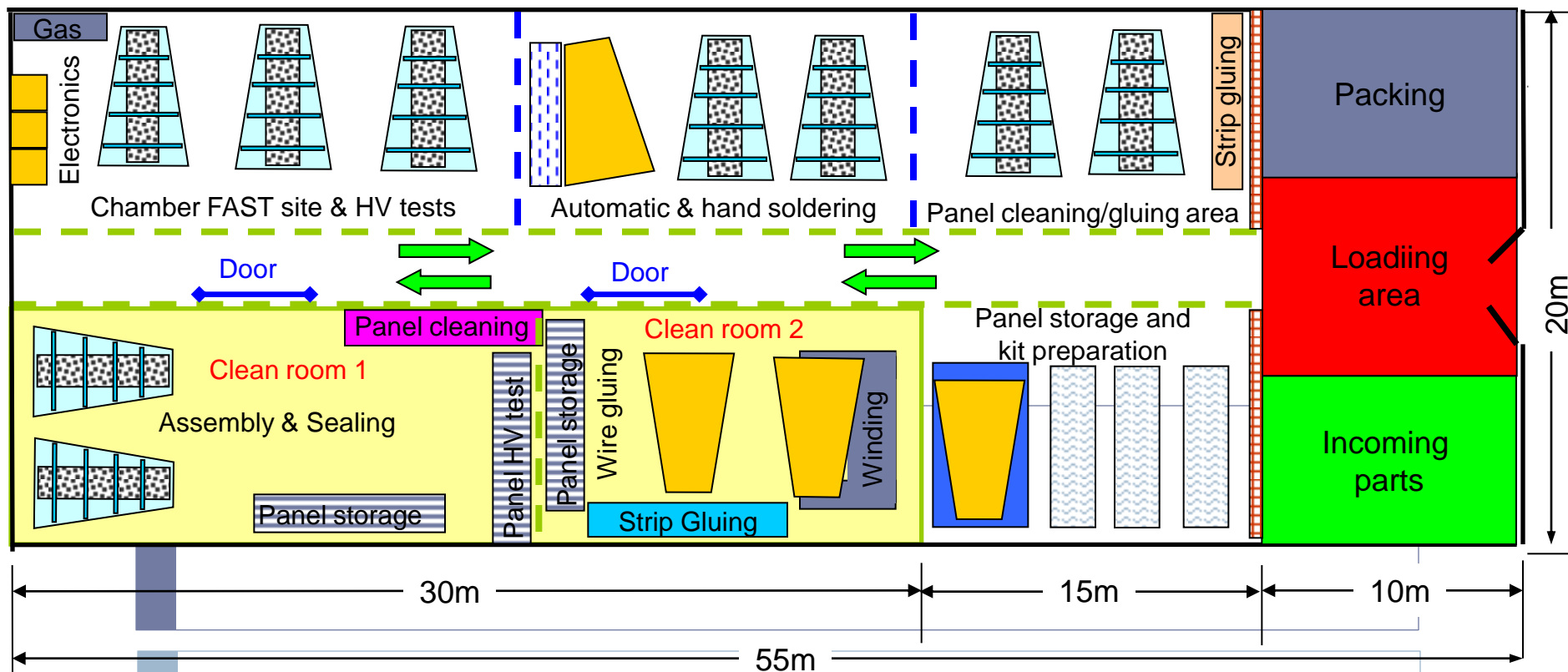
Phase 1 : Muons ME4/2 upgrade motivation



- ▶ 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 I trigger threshold is reduced from 48 \rightarrow 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 ~ 250m².

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)
 - ▶ Including the case where we achieve luminosity using 50ns bunch spacing – giving higher number of interactions/bunch
 - ▶ 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

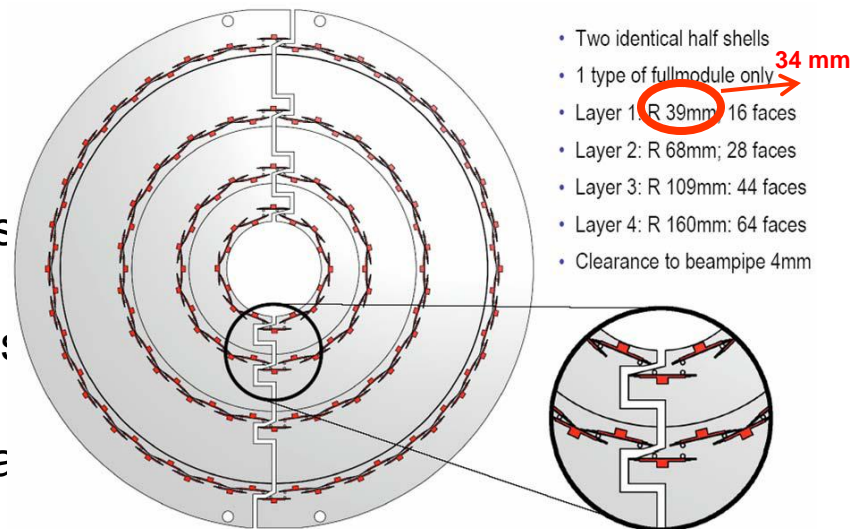
- Inner layers and inner disks: designed for easy and fast replacement.

- 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)

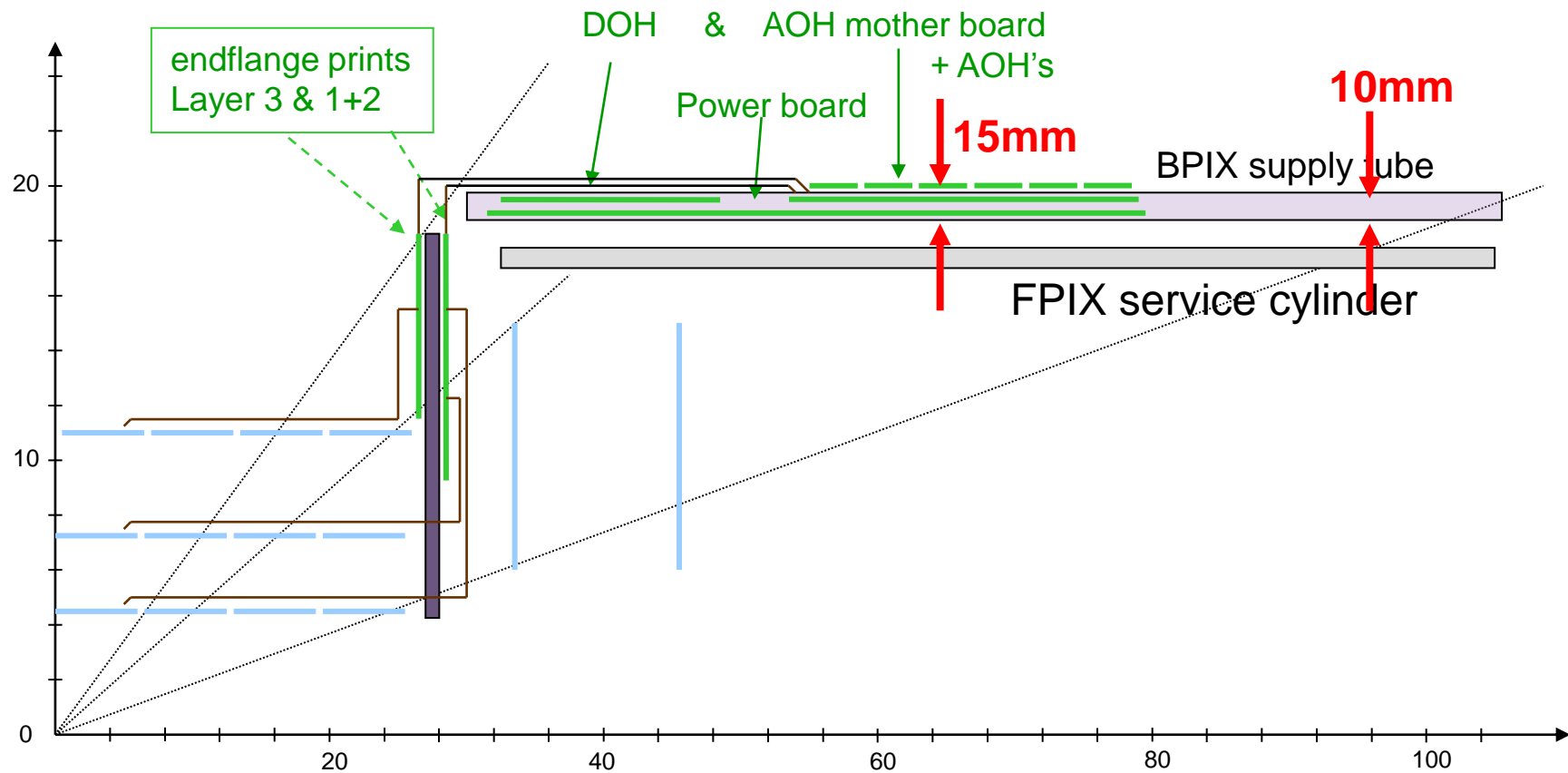
- Material budget: aim for major reduction (at least 60% reduction)

- 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 ($75\mu\text{m} \times 100\mu\text{m}$ or smaller) & thinner sensors

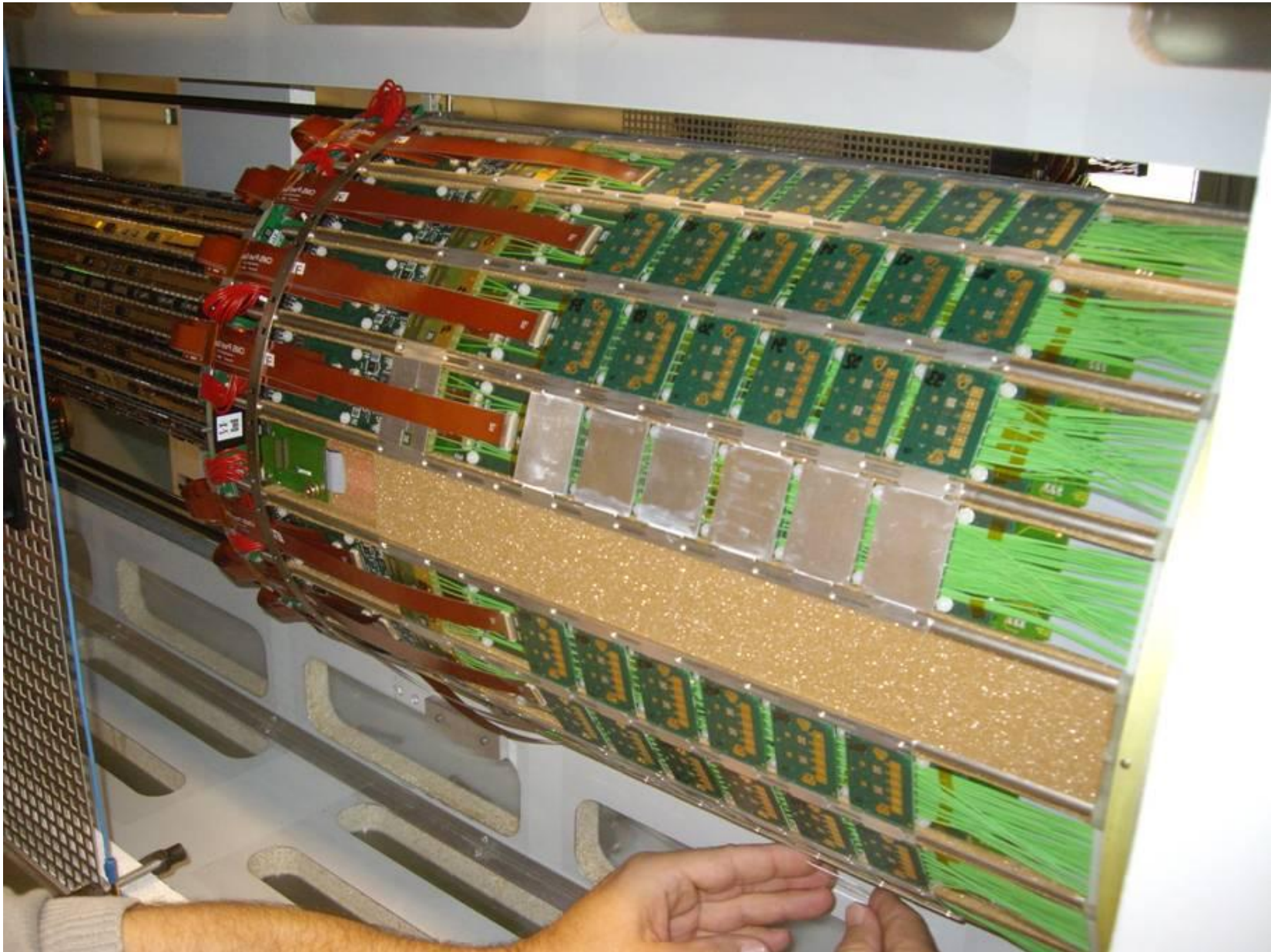


Current Pixel System with Supply Tubes / Cylinders

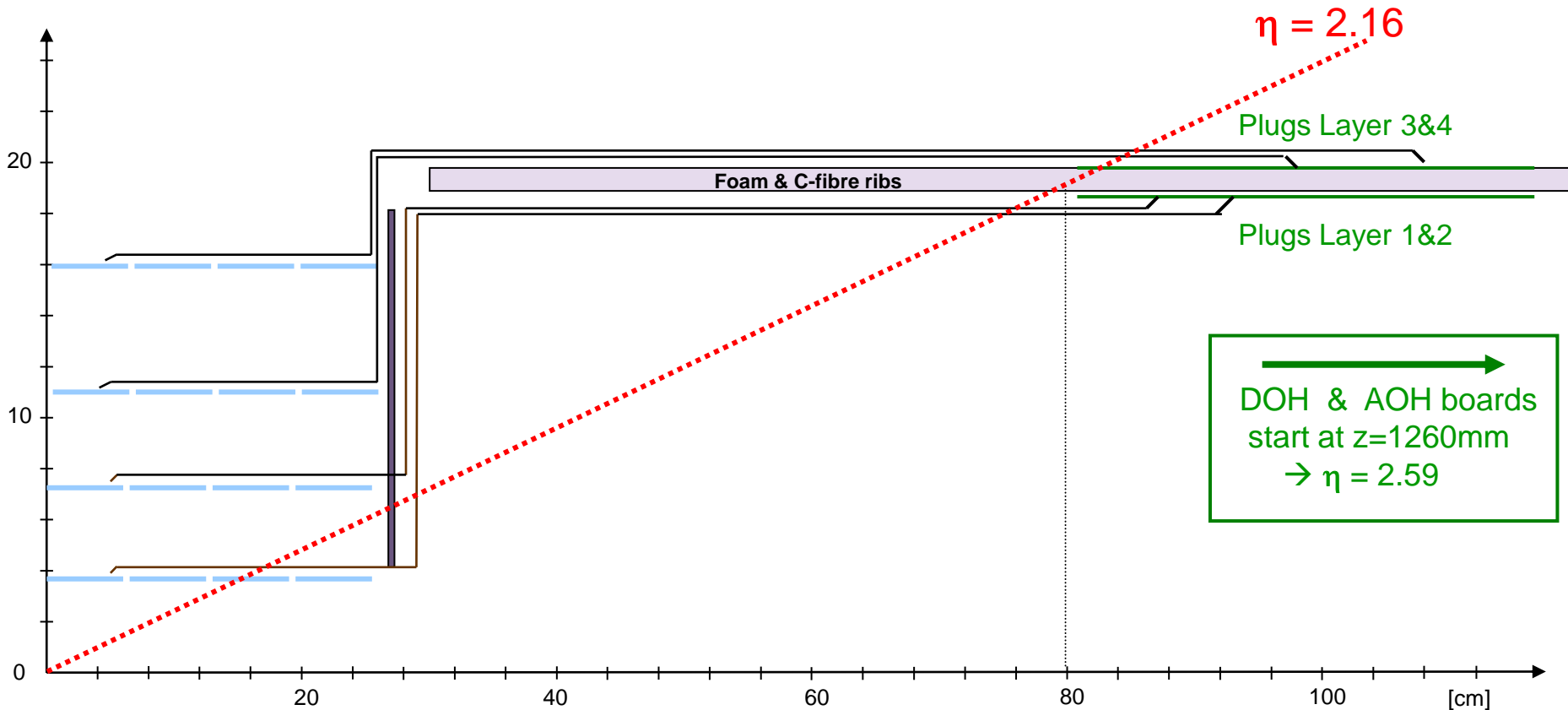
Thickness of Supply Tube
→ inserstion envelope for FPIX



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



Weight of 2015 Phase 1 Pixel System (4 layers)



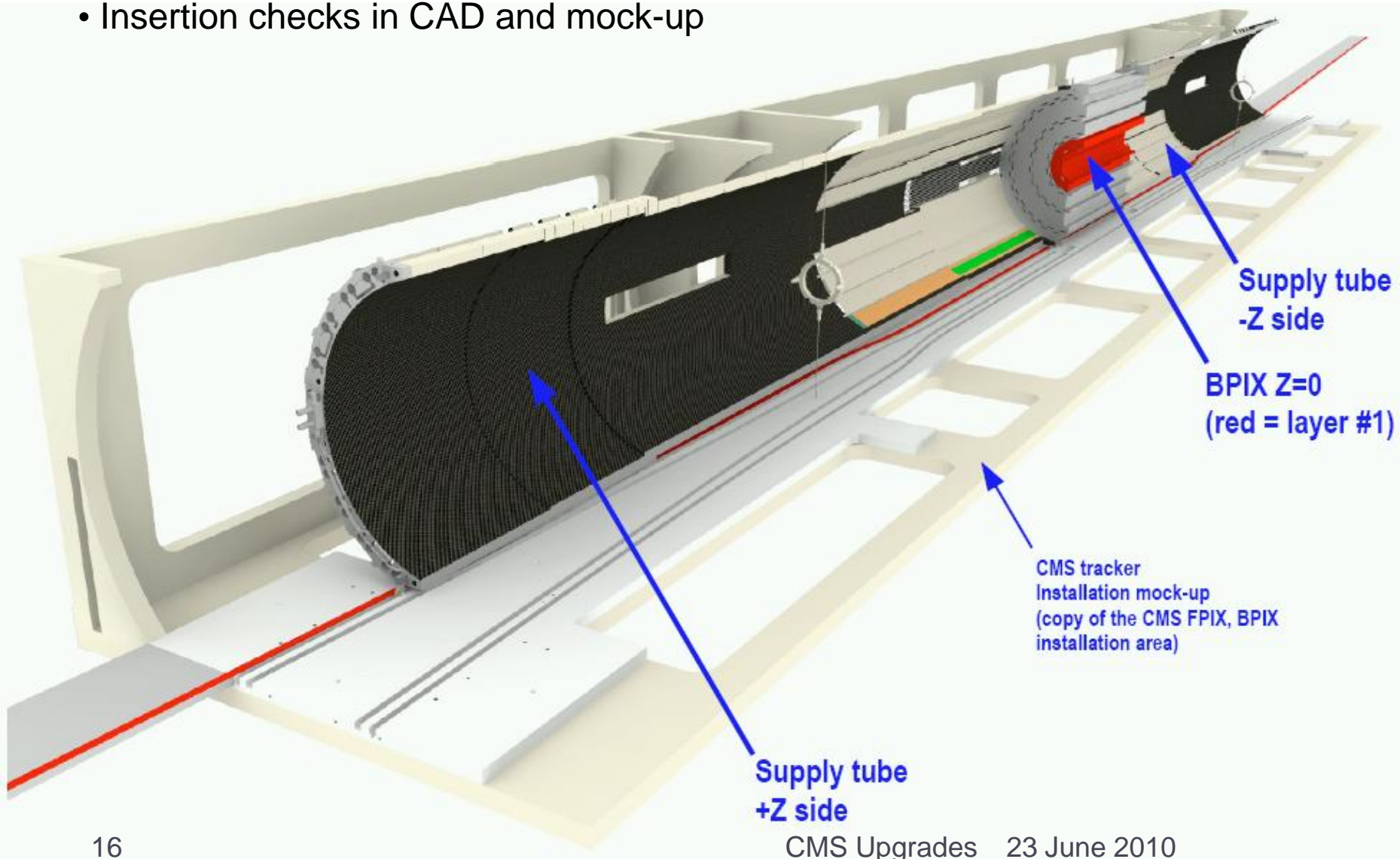
Total weight of 2014 4 Layer BPIX within $\eta < 2.16$: 6454 g ~ 6.5 Kg

2 Barrels & 4 Supply Tube Sections & CO₂ & Cables

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

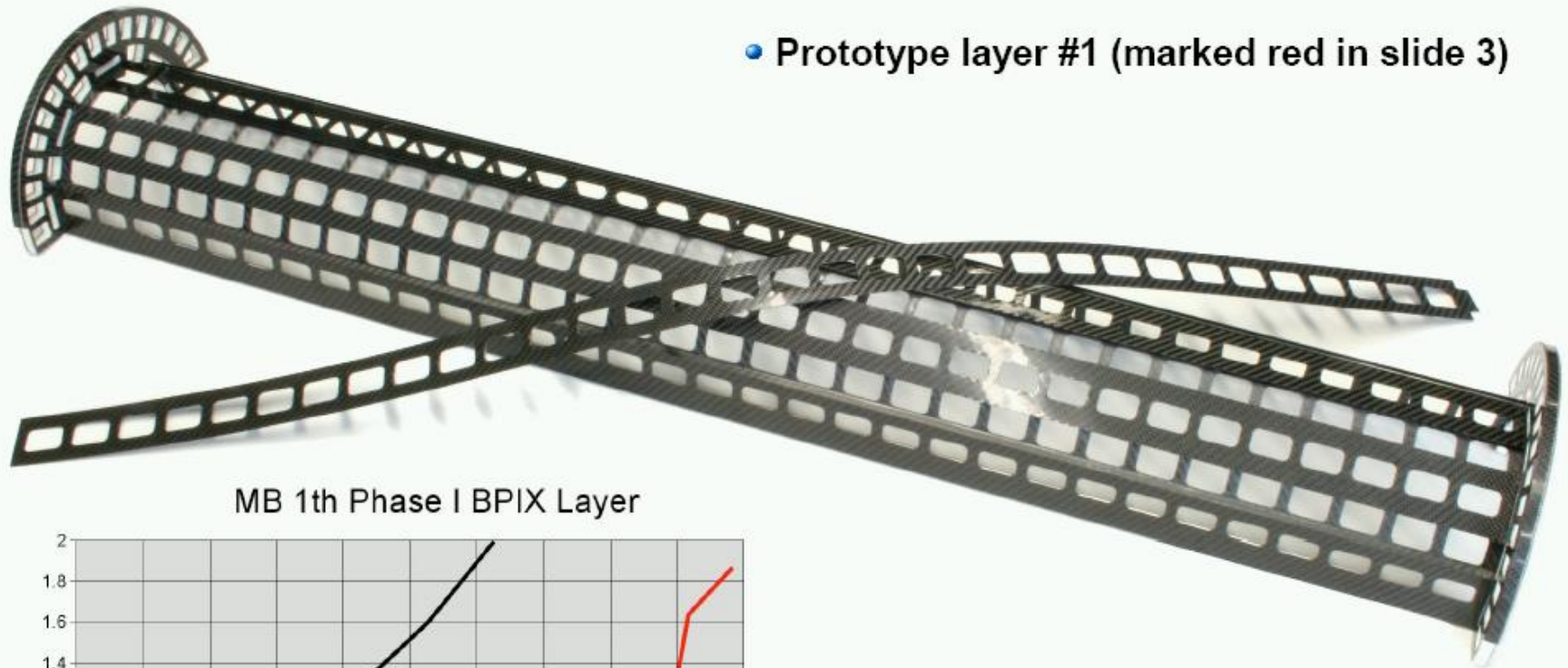
Overview of 2015 4 Layer BPIX System

- Insertion checks in CAD and mock-up

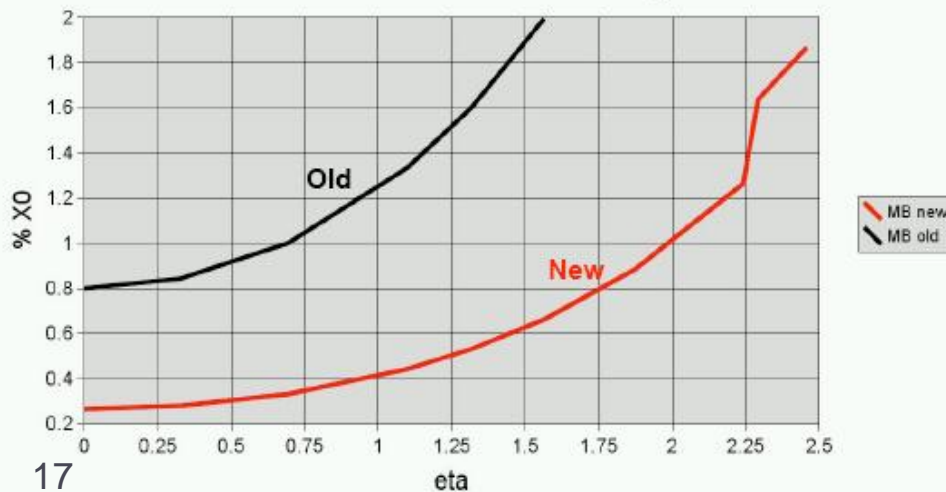


1 Layer of new Ultra Light Mechnaics

- CO₂ cooling circuit (50 μ m wall thickness tubes) pressure tested to 100 bar

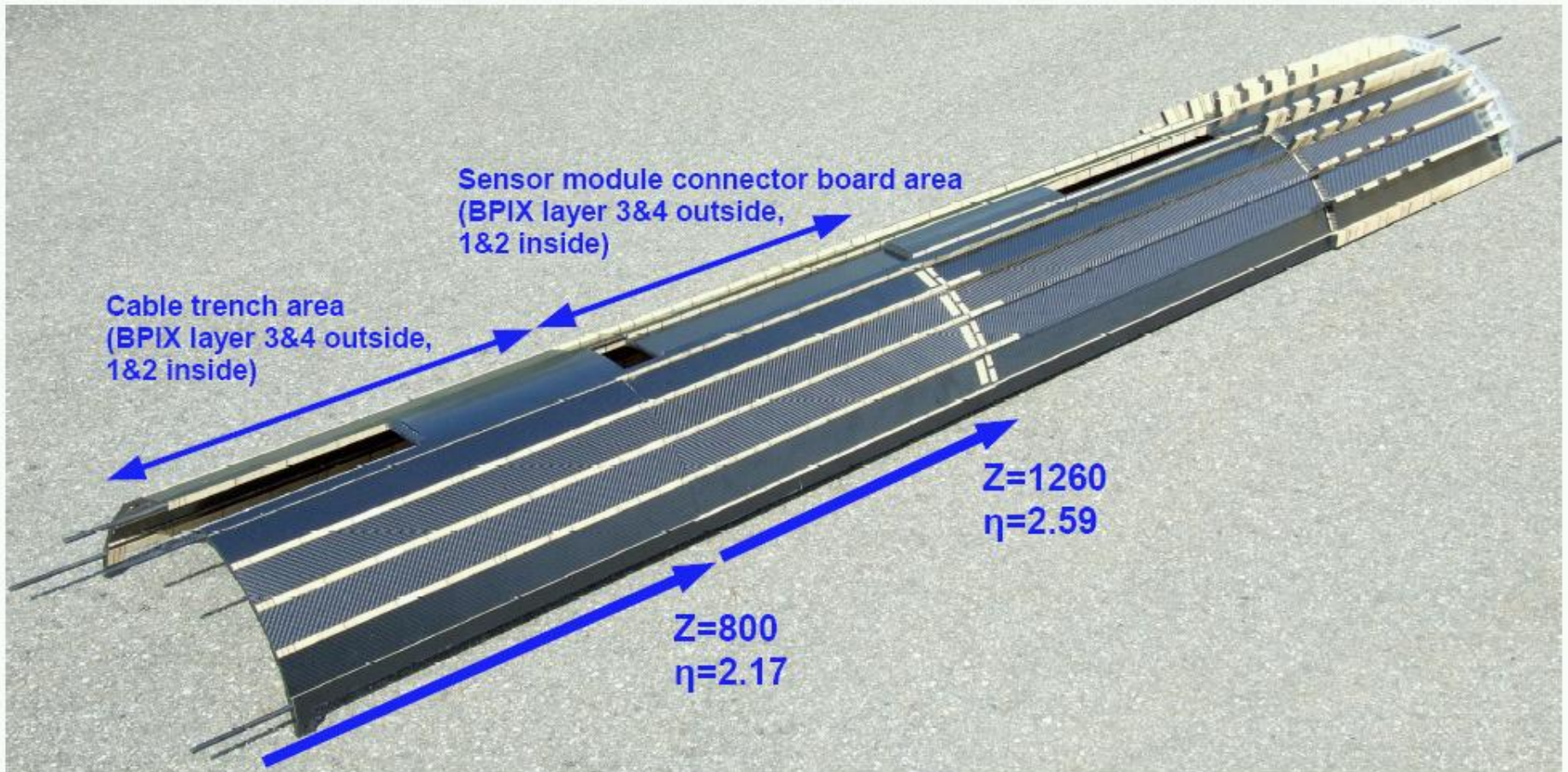


MB 1th Phase I BPIX Layer



- **New material budget is 30% off current BPIX**

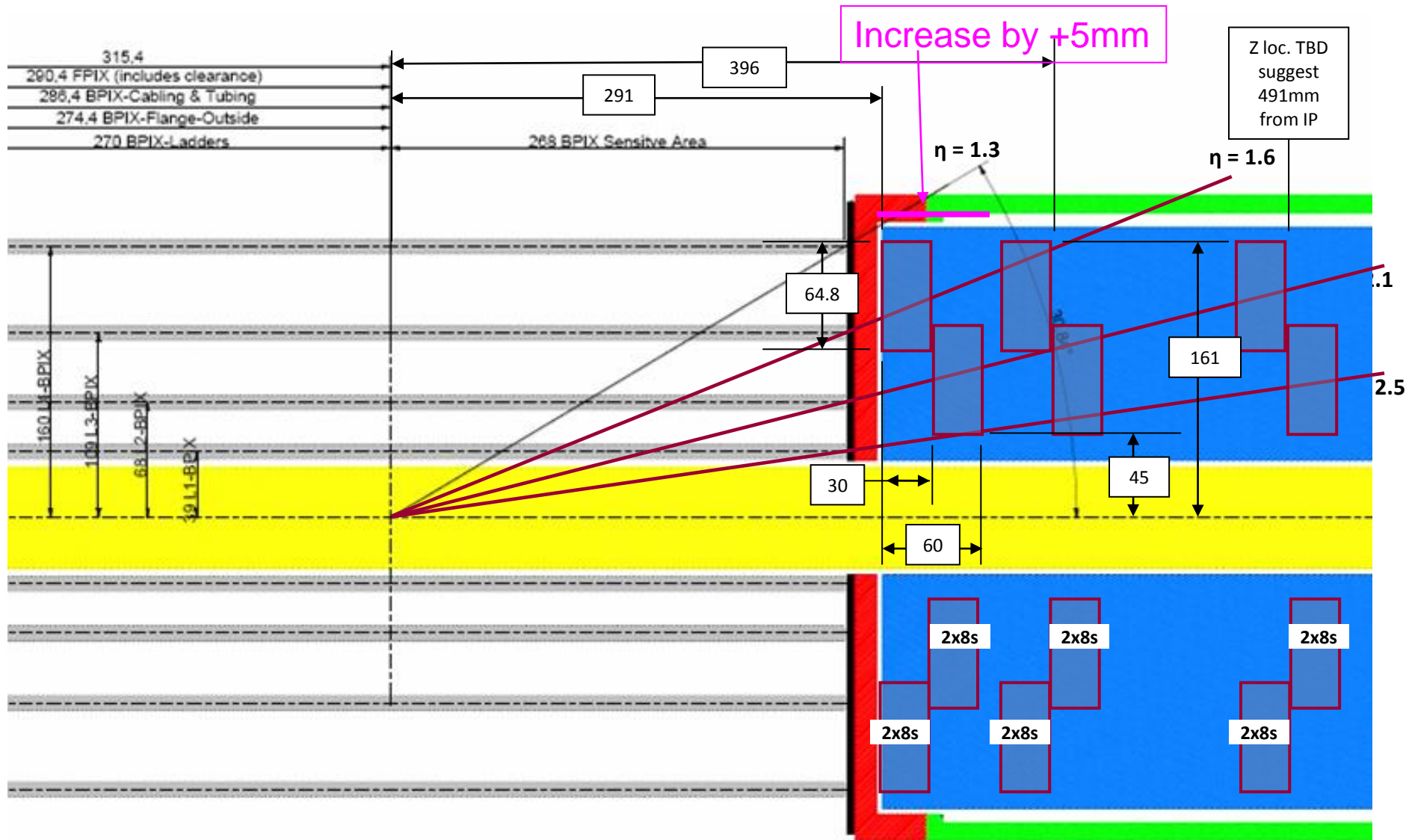
New BPIX Supply Tube



• **Note: Some minor carbon fiber parts not yet glued.**

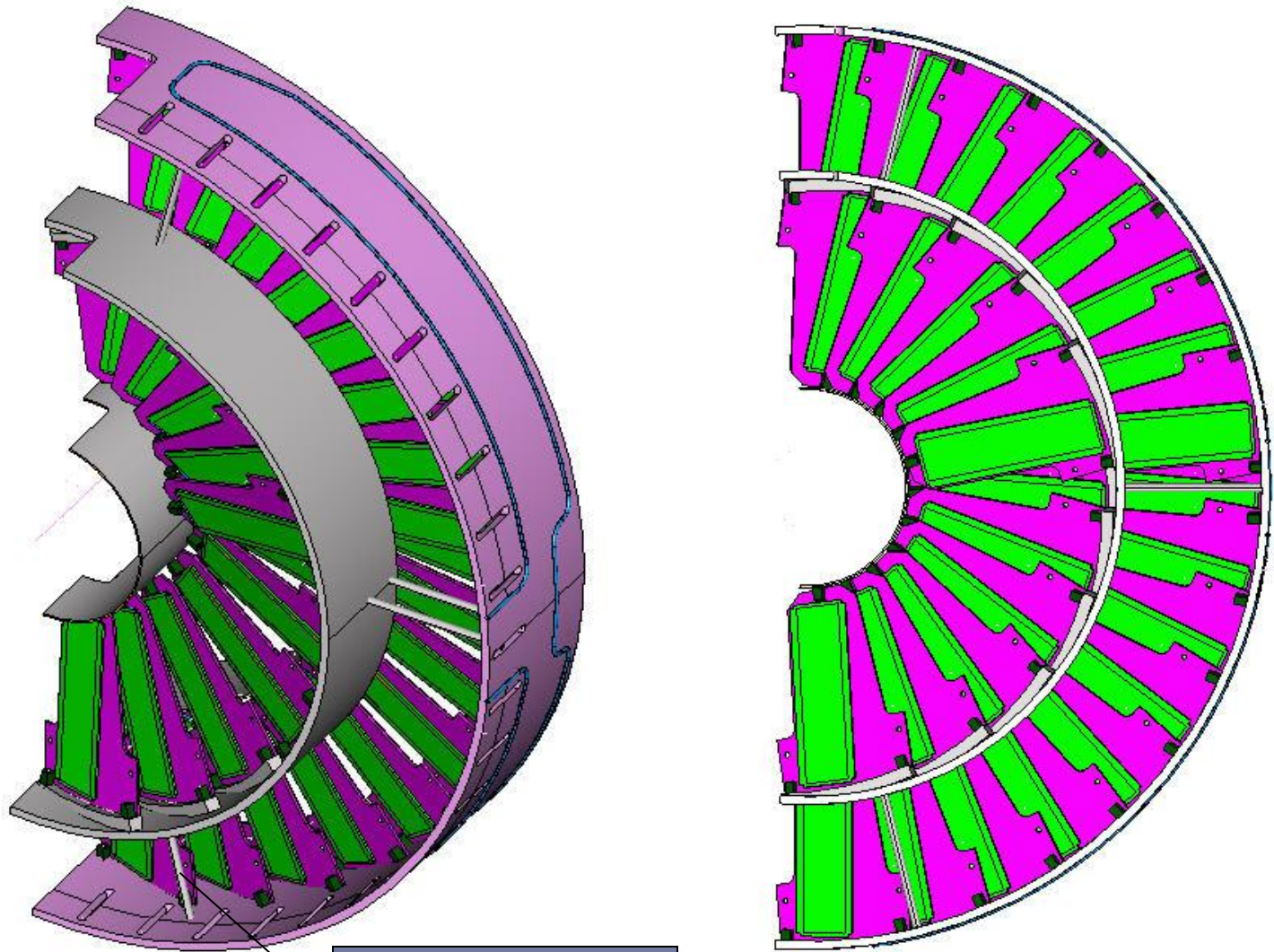
• **CO2 cooling loops are to be inserted**

BPIX / FPIX Envelope Definition for 4 Hit Pixel System



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

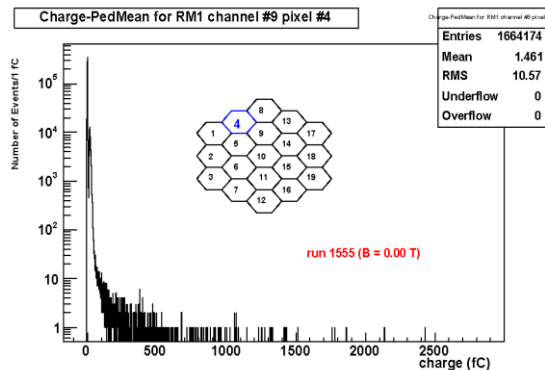
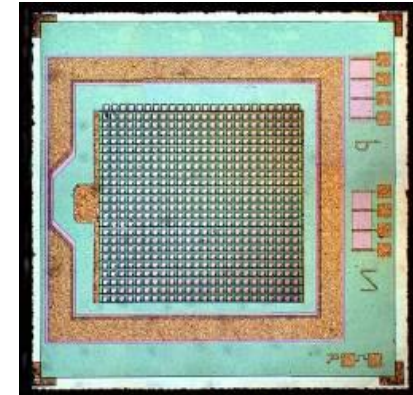
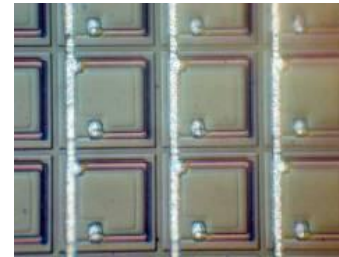
The Half Disk (to be completed)



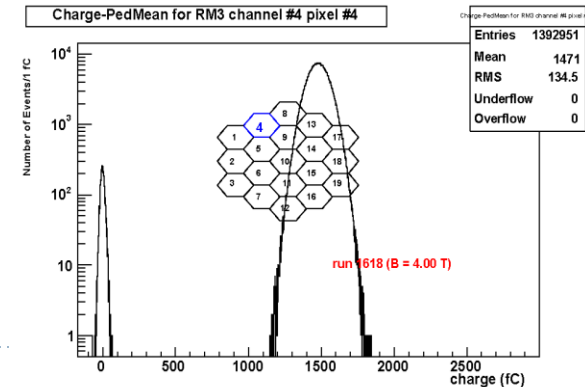
Carbon fiber supporting spokes

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 mm²
 - ▶ 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 10⁶ gain (x500 higher)
 - ▶ More light (40 pe/GeV), less photostatistics broadening
 - ▶ Very high gain can be used to give timing shaping/filtering

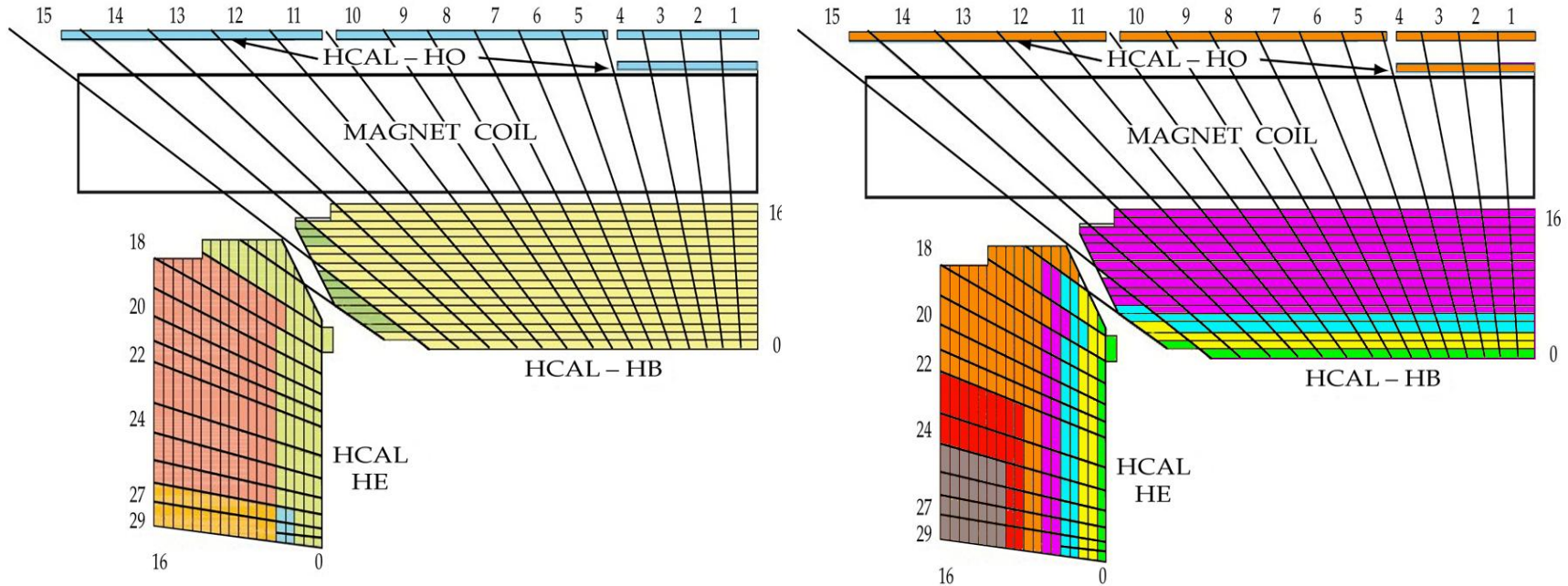


HPD



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

Technical Coordination: Shutdown planning 2011-13: 1st draft

Time	Est. Int. Lumi/fb- l	Tasks	Logistic Scenario
2011-2013	30-50	Infrastructure modifications (i-ix)	fully open both ends
		Test beampipe region RP shielding	
		HO & CASTOR phototransducer change	
		YE4-z shielding wall/YE4+z shielding wall	
		4 th muon endcap station -z (CSC + RPC)(+ possibly RPC for +z)	
		CASTOR, TOTEM, ZDC removed for pp	
		Pixel Luminosity Telescope (PLT) installed.	
		BSC extension, FSC completion	
		ZDC crane installation	

After which CMS should be ready for 6.5 TeV, 50fb⁻¹ and 1-2 x 10³³

Technical Coordination: Shutdown planning 2014-16: 1st draft

Timeframe	Est. Integrated Luminosity/fb- l	Tasks	Logistic Scenario
2014-2016	30-50	central beampipe, $\phi \rightarrow 50\text{mm}$	fully open both ends
		Pix/BCM removed, bakeout required	
		HB/HE front end re-build +z and -z	
		HF phototube replacement +z and -z	
		1 st muon station readout granularity +z and -z	
		Muon barrel front-end revision	
		4 layer, low-mass pixel tracker	
		BSC replacement.	
		Trigger modifications for high lumi	

After which CMS should be ready for 7TeV, up to 700fb⁻¹ and 2×10^{34}

Technical Proposal

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

Technical Proposal Progress...

On track for September submission

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Conclusions

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