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ATLAS & CMS Muon System Special Needs

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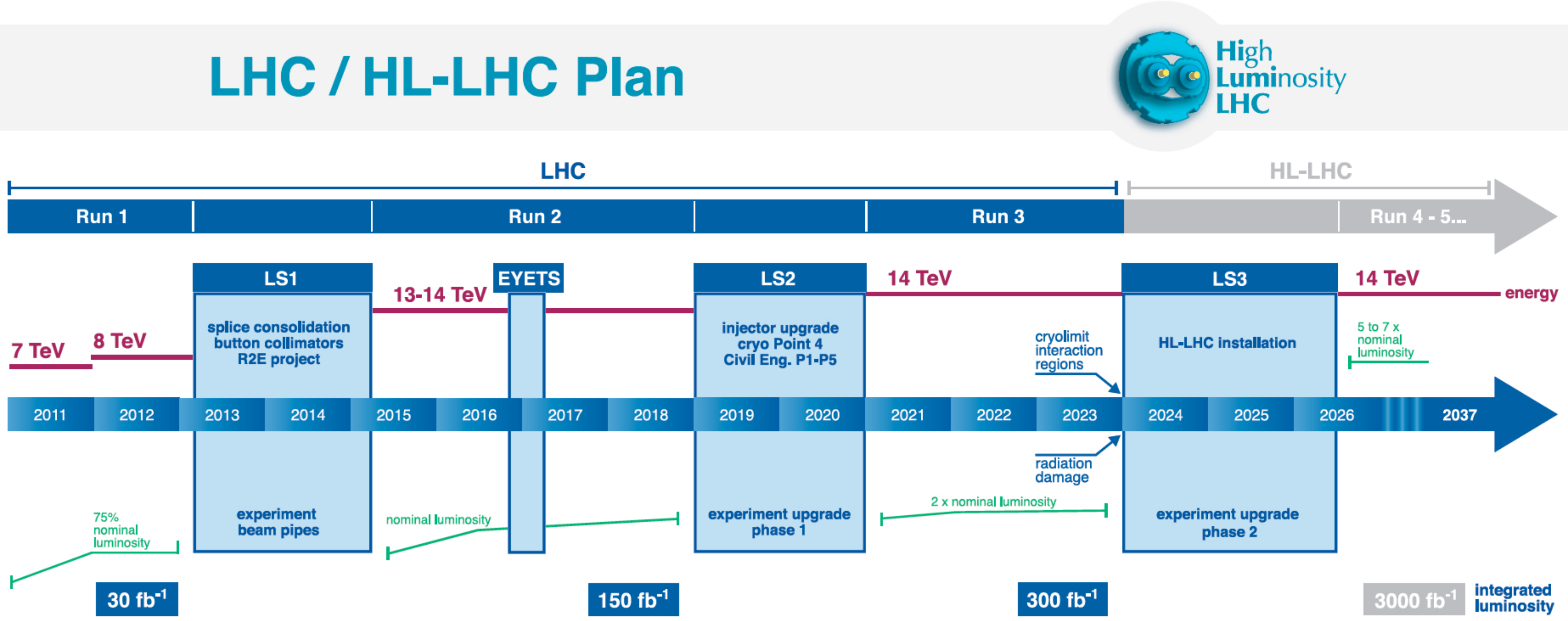
LHC Timeline



LHC luminosity to increase by an order of magnitude by time of HL-LHC commissioning

Particle fluxes and rates in the detectors to increase an order of magnitude

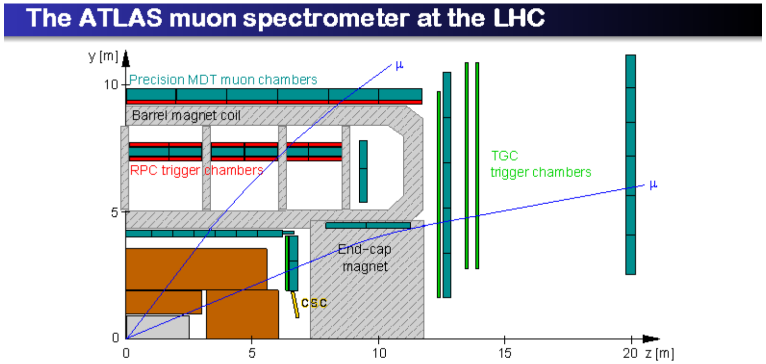
- Significant detector upgrades are needed to maintain operation

ATLAS and CMS Muon Systems will require series of upgrades during LS2 and LS3 as well as EYETS 2016-2017

- Activities during LS1 have provided experience with issues relevant to our upgrade efforts

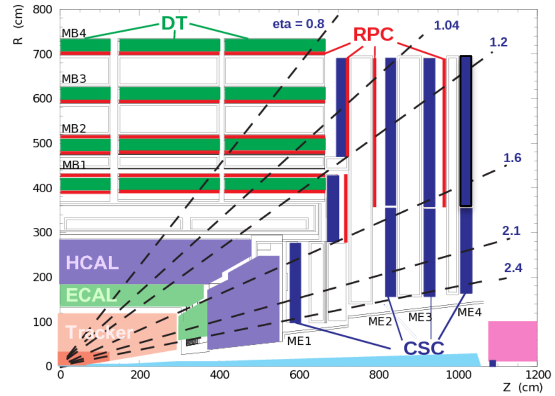
Muon System Run 2 Configurations

ATLAS



- Fast trigger chambers: RPC, TGC
  (< 10 ns time resolution, moderate spatial resolution □mm-cm).
- High-resolution tracking detectors: CSC, MDT (40 μm spatial resolution).
- Optical alignment system with 50 μm resolution.
- Pseudorapidity coverage: $|\eta| < 2.7$.

CMS



CMS Muon System:

Drift Tube system in Barrel (green)

RPC Chambers in Barrel and endcap (red)

CSC Chambers in endcap (blue)

Systems are quite similar despite very different global detector designs

- Gas detectors
- Technologies are DT, RPC and CSC
- Use LV supplies located close to (10-20m) detector
- HV supplies located in service caverns

What is special about the muon systems?

- Being outermost, they are widely dispersed
- Very heterogeneous
- Services are very heterogeneous

Power Supply Experience During Run 1

ATLAS:

- Following initial infant-mortality problems, failure rate was acceptably low and consistent with regular operation up to LS3
- Noted that some PS components are becoming difficult to find. May present problems for repairs in future

CMS:

- Also observed infant mortality issues during initial commissioning. Failure rate of boards is now acceptably low and constant. No observed increase in failure rate with time.
- Also noted that parts for repairs becoming difficult to find
- Experienced slow operation with SY1527 mainframes, attributable to serial operations with high channel counts. Partially solved by optimizing for parallel operation, more robust solution found by upgrading to SY4527
- Observed that dust is major hazard to HV systems

Longevity Expectations: ATLAS

- ATLAS Muon System:
  - With the present schedule, LHC is planned to deliver 300 fb^{-1} up to the end of Run3 in 2022, reaching 3000 fb^{-1} in the ten years after LS3. Taking in account what seen before in terms of reduction of the safety factors on simulation, and the 25% higher TID for Muon Barrel and NSW, the expected survival time of the present PS distributors is around **1700 fb^{-1}**. Speaking of time, they should stop working in 15 years from now

  - The increase of PS channels, due to the various upgrades, will probably create a serious bottleneck to the DCS with the present systems. This problem was already evident in Run1, and partially solved by replacing the mainframes for Run 2. But in order to take profit of the new communication protocol FlexRay, also the Branch Controllers on both the mainframe and the distributor sides must be replaced.

Longevity Expectations: CMS

DTs:

- Primary concerns are maintenance concerns with on-detector electronics. Partially mitigated by moving part of trigger electronics to service cavern during LS1.
- Expect stable maintenance scenario with LV & HV supplies up to LS3
- Studying development effort for new prototype of A877 HV supply in time for LS2, under discussion with vendor
- In discussions with vendor to secure adequate reserves of replacement parts
  - This may be more suited to joint ATLAS-CMS effort

RPCs:

- Expect to upgrade to SY4527 mainframes by LS2
- Also expecting stable maintenance scenario with LV & HV supplies up to LS3

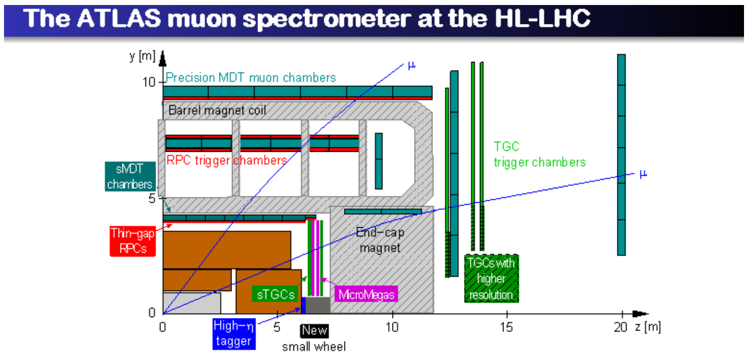
Longevity Expectations: CMS

CSCs:

- After 10 years at HL-LHC with L = 5x10^34 and a n-fluence of 3x10^12 n/cm2 expect ~8krad at hottest CSC points (innermost part of ME1/1)
- Maraton LV supplies: Built for operation at LHC. Tested up to 14 krad or 5.6x10^12 n/cm2 or 3x10^12 p/cm2, B-field tolerance up to 1300G
- HV: 20% of spares for Distribution boards. On top of that, have ~5% of regulator spares, ready for replacement
- Normal failure rate is around 10 channels per year, out of 9000 channels, so 0.1% per year. Experienced higher rate in 2015 because of infant mortality of new ME4/2 boards; should stabilize in 2016.
- Even if the rate grows to 1% per year, expect spares alone will be adequate at least to LS3

Muon System Upgrade Configurations

ATLAS



- New small wheel with high-resolution trigger chambers to reject fake muon triggers and improve momentum resolution at trigger level.
- New TGCs with higher resolution to cope with background at |η| 2.7.
- New thin-gap RPCs to close acceptance gaps of the barrel muon trigger.
- New sMDT chambers to free space for new RPCs.
- High-η tagger to identify muons up to |η| = 4.0.
+ New on- and o -chamber electronics for new trigger architechture.

New small wheel to reject fake muon triggers

  Composed of sTGCs and MicroMegas

New higher resolution TGCs at eta ~2.7

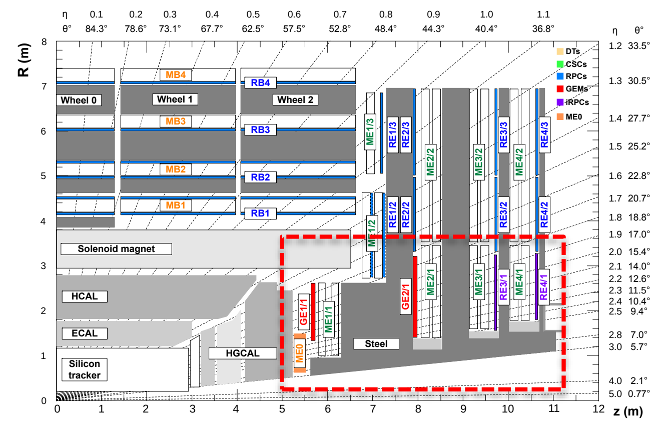
New thin-gap RPCs in the inner barrel to maximize acceptance

  Thinner MDT plane to make installation of thin-gap RPCs possible

TGC high-eta tagger

Use MDT data in first-level trigger

CMS



A quadrant of the CMS muon system, showing DT chambers, RPC, and CSC. The locations of new forward muon detectors for Phase-II are contained within the dashed box showing the GEM stations (ME0, GE1/1, and GE2/1) and improved RPC stations (RE3/1 and RE4/1).

Replace DT on-chamber electronics

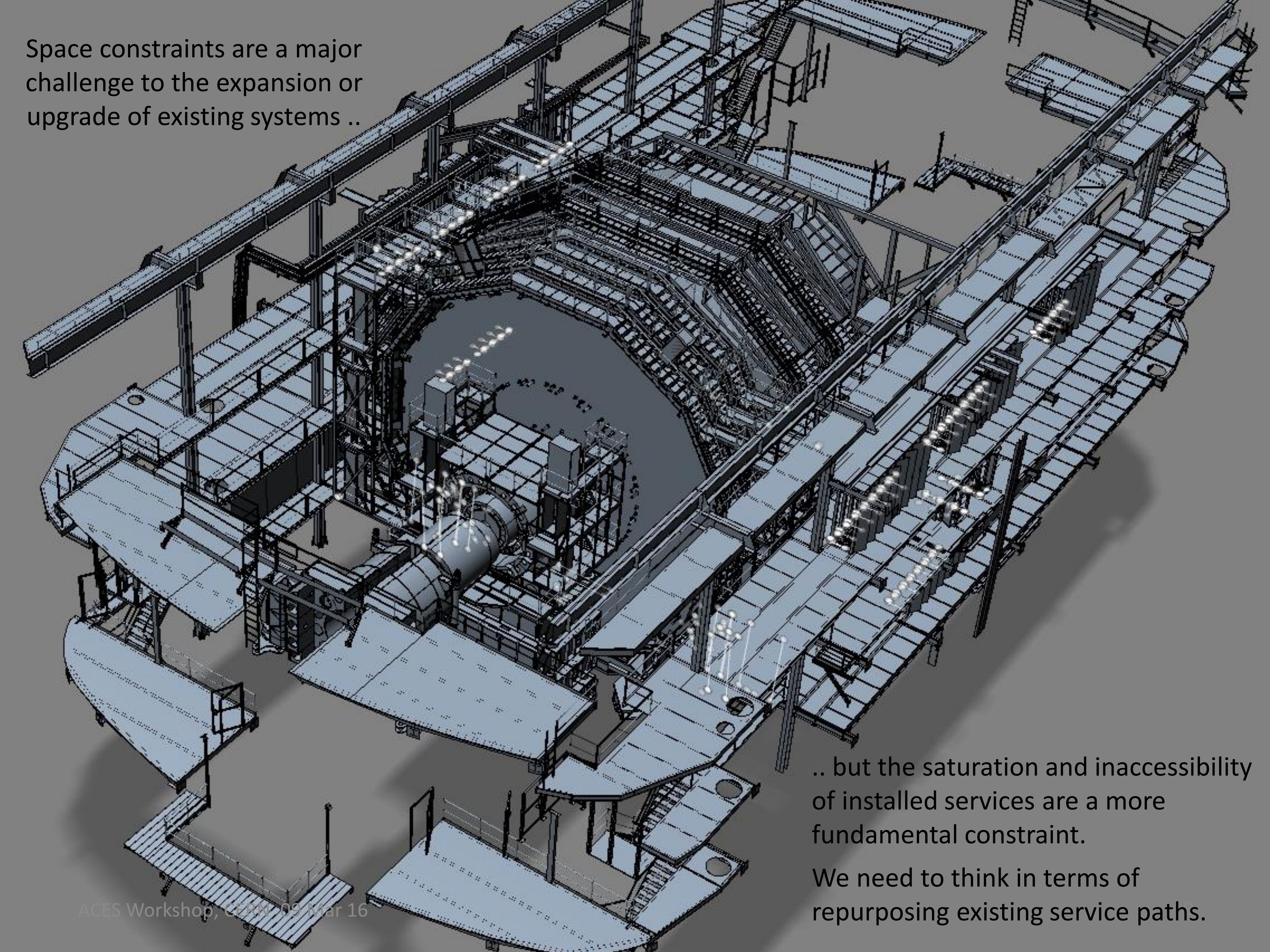
Move DT trigger electronics to service cavern

Upgrade cathode front-end boards on inner rings of layers 2, 3 and 4

  May need to consider doing this during LS2

Add two planes of inner ring RPCs in endcap layers 3 and 4

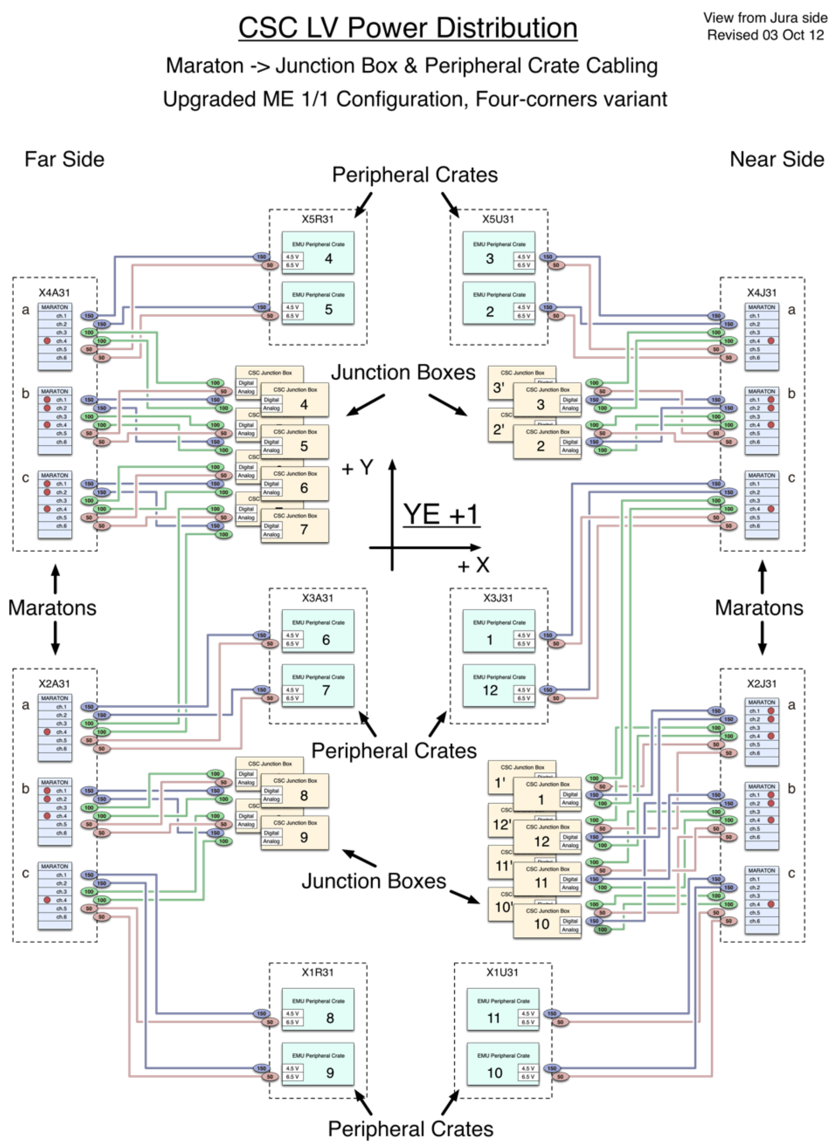
Two planes of GEM detectors and ME0 detector at high eta


Space constraints are a major challenge to the expansion or upgrade of existing systems ..
.. but the saturation and inaccessibility of installed services are a more fundamental constraint.
We need to think in terms of repurposing existing service paths.

Case in Point: Upgrade of CMS ME1/1 Chambers

- Front-end electronics of innermost ring of first plane of CMS endcap CSCs was upgraded during LS1
  - Upgrade involved replacing cathode front end board with new version using flash ADCs (DCFEB), and increasing number of boards per chamber from 5 to 7
- What we needed to change
  - Number of on-detector LV (Maraton) supplies
    - DCFEBs & new peripheral crate electronics have increased power requirements
  - Number of rectifier modules (OPFCs) in service cavern
    - One OPFC per Maraton
  - Number of junction (fanout) boxes
    - Cannot parallel Maraton outputs
  - New on-chamber LV regulator boards
    - To accommodate 7 DCFEBs instead of 5
- What we *did not* need to change
  - Power cabling through main cable chains between service cavern and experimental cavern
    - Spare conductor pairs existed in CSC primary power cables
  - Rack power distribution boxes
  - CANBus readout cabling
    - Serial chain was extendable
  - LV cabling to upgraded CSCs
    - This cabling is inaccessible as it runs under the outer two rings off CSCs
    - No cable paths are available over or between outer rings of CSCs for routing new cables
    - Initial indications were not encouraging since increased current draw of DCFEBs resulted in cable voltage drop in excess of what would provide adequate target voltage at load

Repartitioning of CMS ME1/1 CSC Power



- Simplest repartitioning involved splitting inner & 2 outer rings
  - Each 30-degree trigger sector was allocated two junction boxes
  - Cables between junction boxes and chambers were reused
- Splitting upgraded chambers from outer two rings allowed us to set voltage of upgraded channels independently
- Upgraded LV regulator boards on inner chambers allowed us to take advantage of lower voltage requirements of new electronics on DCFEBs to offset increased voltage drop on cables
- This happened to be a case of several fortunate coincidences, but a more general lesson remains:
  - Design of detector upgrades may need optimization in order to accommodate limits of services infrastructure
  - We need to be aware of what those limits are

Summary …

- Component reserves: ATLAS & CMS need to work together with vendors to identify components most at risk of obsolescence
  - Will most likely involve contractural arrangement
  - Preferable to approach as common project rather than have subdetectors arrange individually with vendors
- Product longevity:
  - Product lifecycles are getting shorter
  - HEP timescales are getting longer
    - Availability of essential equipment may become critical issue approaching the end of a run
    - Consider this as engineering issue in the design phase of new projects
- Constraints imposed by services:
  - Again, consider folding these constraints into initial design process
- HV & LV replacement scenarios for HL-LHC:
  - ATLAS & CMS should consider optimizing requests to vendors to minimize development overhead & delivery delays.
  - Consider developing common architectures