Highlights from CMS Upgrade Week at DESY-Hamburg 17 June 2013

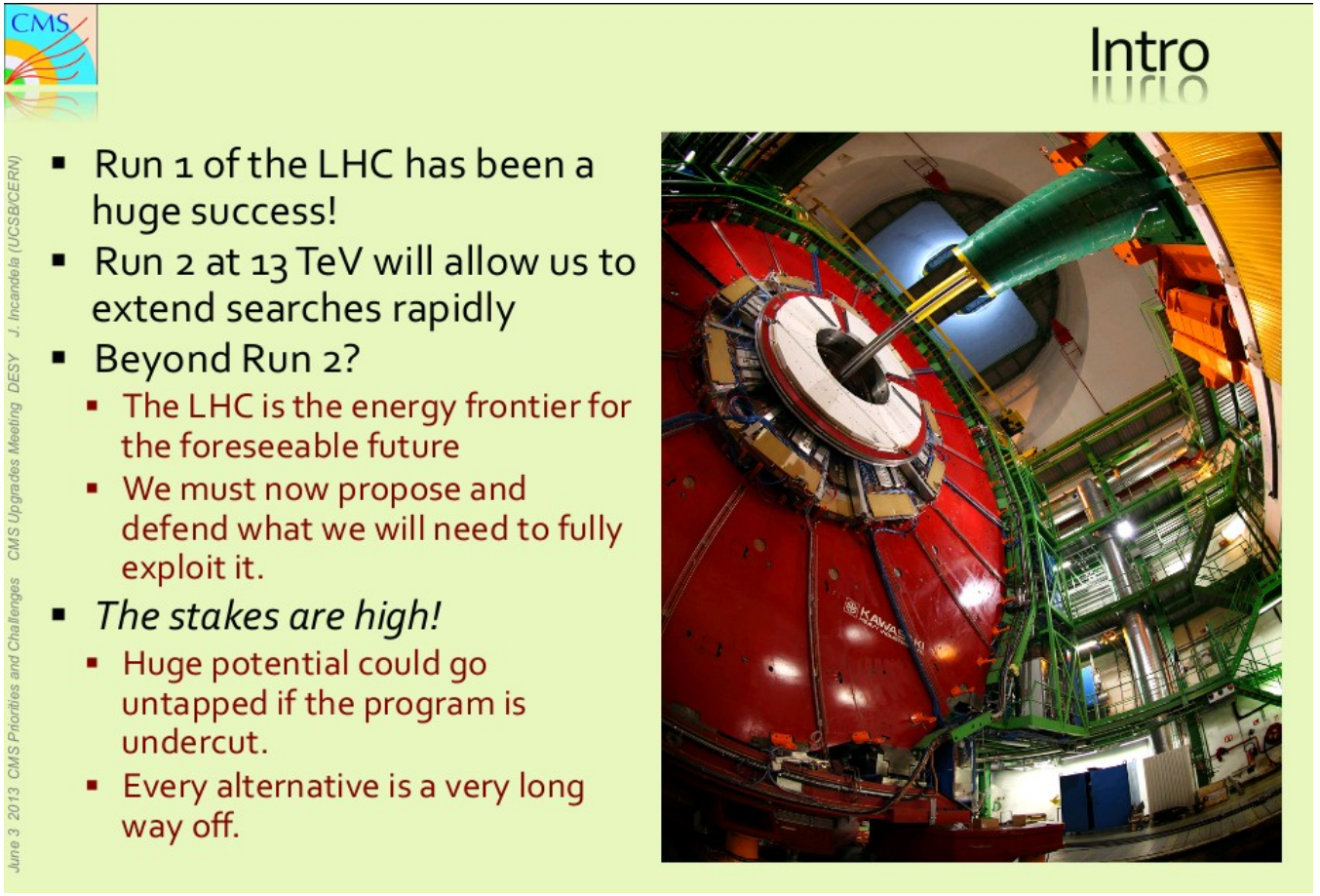
Agenda

https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=236161

Progress on Phase 1

Main focus on Phase 2

- Scenarios
- Simulations
- Preparations



Phase 2 Physics

Post LS3 (HL-LHC) Physics Program

- **Measure properties of the Higgs boson**
  - couplings, J^{CP}, differential cross sections, mass
  - self-coupling (di-Higgs production)
  - rare decay modes (e.g. H → μμ, H → Zγ, ttH, H → γγ)
  - weak boson scattering
- **Search and hopefully measurement of SUSY, Exotica, BSM Higgs, etc.**
  - natural SUSY (low mass gluinos and stops)
  - high mass searches, e.g. W' & Z'
  - exotic signatures, heavy stable particles
  - rare processes
- **SM measurements**
  - support searches, e.g. PDFs
  - SM null tests, e.g. FCNC top decays
- **Flavor physics**
  - e.g. τ → μμμ, B^0 →μμ

See talks and discussion by Joe and Chris earlier today (I have not seen them before preparing these slides)

We should not confuse the post-LS3 physics program with channels driving design choices

Detailed discussion of the physics program should be part of a TDR

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Phase 2 Reference Channels

DRIVER EDUCATION

Physics Channel to Drive Design

- **Taxi driver**
  - HH → bbγγ
    - b-tagging, di-jet mass, photon id and resolution
  - VBF H → ττ
    - forward jet tagging, central jet veto, hadronic tau reconstruction, electron and muon id, missing energy resolution, low pT trigger thresholds

- **Taxi passenger**
  - HH → bbττ
    - covered by HH → bbγγ and VBF H → ττ
  - H → μμ
    - covered by VBF H → ττ, additional requirement is muon resolution
  - H → γγ / H → ZZ ratio
    - covered by HH → bbγγ and VBF H → ττ
    - to illustrate coupling measurement reach
  - WW scattering (lvlvqq)
    - covered by VBF H → ττ
  - BSM Higgs to invisible
    - covered by VBF H → ττ, additional requirement is large MET
  - high mass di-jet resonances
    - "covered by VBF H → ττ", additional requirement is high-pT central jets
  - the list can be extended to cover the full HL-LHC physics program

Markus Klute

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LHC Upgrades

Working assumptions for the LHC Luminosity Upgrades

8 TeV - 30 fb^{-1}

up to 7.7 x 10^{33} Hz/cm^2 , 50ns Bunch Spacing, <PU> up to <21>

LS1
2013-14

Repair splices - batch compression in PS - SPS scrubbing…
Startup at 13 TeV [?], with potential for brighter bunches

p-p: 1 → 1.6 x 10^{34} Hz/cm^2, <PU> 25 → 40, 25ns, ~ 120 fb^{-1} by LS2
(50ns fall-back would require lumi-leveling)
Pb-Pb: $\sqrt{s_{NN}}$ = 5.5 TeV - 3 x 10^{27} Hz/cm^2 → 3 nb^{-1}

Phase 1
13/14 TeV
300 - 500 fb^{-1}

LS2
2018

Increase beam brightness - injector chain upgrades: New Linac - PSB-PS at 2 GeV, RF upgrades in PS and SPS …

p-p: 2 → 2.5 x 10^{34} Hz/cm^2 , <PU> ~50-75, 300-500 fb^{-1} total by LS3
Pb-Pb: 6 x 10^{27} Hz/cm^2 → 6 nb^{-1} (plan for Ar)

LS3
2022-23

Replace low-β quadrupoles (radiation aging) → improved beam spot, crab-cavities to optimize beam overlap, collimator upgrade…

Phase 2
HL-LHC 14TeV
≳ 2500 fb^{-1}

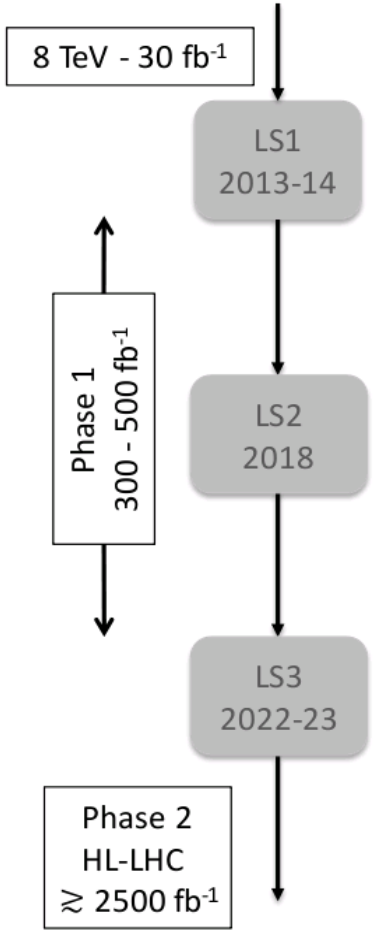
Capability: peak lumi >1 x 10^{35} Hz/cm^2 . Lumi leveling to optimize integrated luminosity vs detector performance - target 5 x 10^{34} Hz/cm^2 over fill length
Design for PU 140 (investigate degradation at 200) - 250 fb^{-1} /year

Note: LS2 and LS3 dates will very likely change.
When will quads have to be replaced? what will be the integrated luminosity before LS3 ? …

D. Contardo, J. Spalding

CMS Upgrades

Highlights of CMS Upgrade Program



LS1 Projects: complete detector and consolidate for 1×10^{34} Hz/cm^2, prepare Phase 1 upgrades

- Completes muon coverage (ME4), improve RO of CSC ME1/1 and DTs
- Replace HCAL HF and HO photo-detectors and HF backend electronics
- Install new beam pipe - test slice of FPIX
- Parallel optics and slice commissioning new L1 trigger

Phase 1 Upgrades: largely decoupled from LS2, ready for 1.6×10^{34} Hz/cm^2 by LS2 and up to 2.5×10^{34} Hz/cm^2 by LS3

- Commission L1-Trigger upgrade in parallel to operation during 2015
- Be ready to install new Pixels in extended YETS in 2016/17
- Replace HF FE in YETs and HB/HE photo-detectors and FE in LS2

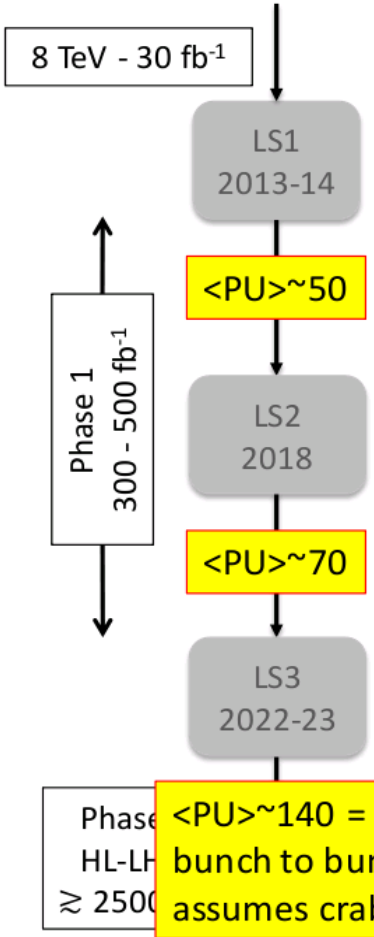
Phase 2 Upgrades: solve detector aging, high occupancy and radiation hardness issues, mitigate PU up to $\gtrsim 5 \times 10^{34}$ Hz/cm^2 Enhance performance where statistics/systematics limited

- Replace Tracker: pixels and silicon – track trigger capability
- Upgrade/replace Forward Calorimeters
- Upgrade Trigger/DAQ: consider Track Trigger, L1/HLT rates increase
- Consider extended η range for Tracker and Muons, precise timing
- Interface to HL-LHC new quadrupoles and shielding

D. Contardo, J. Spalding

CMS Upgrades

Highlights of CMS Upgrade Program



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Phase 2 Upgrades: solve detector aging, high occupancy and radiation hardness issues, mitigate PU up to ≳ 5 x 10^{34} Hz/cm^2 Enhance performance where statistics/systematics limited

- Interface to HL-LHC new quadrupoles and shielding

<PU>~140 = 128 expected mean at 5 x 10^{34} Hz/cm^2 + cross section uncertainty + bunch to bunch fluctuations - Agreed for simulation with ATLAS - Luminous region assumes crab cavity crossing angle compensation and current bunch length rms

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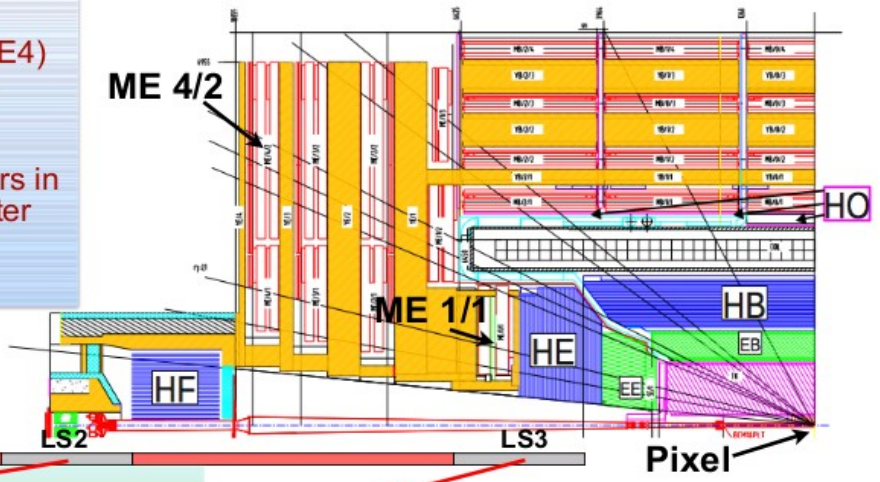
Upgrades Summary

Highlights of upgrade options

CMS upgrade program

LS1 Projects

- Complete Muon coverage (ME4)
- Improve muon operation, DT electronics
- Replace HCAL photo-detectors in Forward (new PMTs) and Outer (HPD→SiPMs)
- DAQ1→DAQ2



Phase 1 Upgrades

- New Pixel detector, HCAL electronics and L1-Trigger upgrade
- GEMs for forward muon det. under review
- Preparatory work during LS1
  - New beam pipe for pixel upgrade
  - Install test slices of pixel, HCAL, L1-trigger
  - Install ECAL optical splitters for L1-trigger

Phase 2: being defined now

- Tracker replacement, L1 Track-Trigger
- Forward: calorimetry, muons and tracking
- High precision timing for PU mitigation
- Further Trigger upgrade
- Further DAQ upgrade

Facing the Scalar Sector, 31/05/2013 LHC: future measurements and reach - Paolo Giacomelli 3

Monday, 3 June 13

Phase 2: Scenario 0

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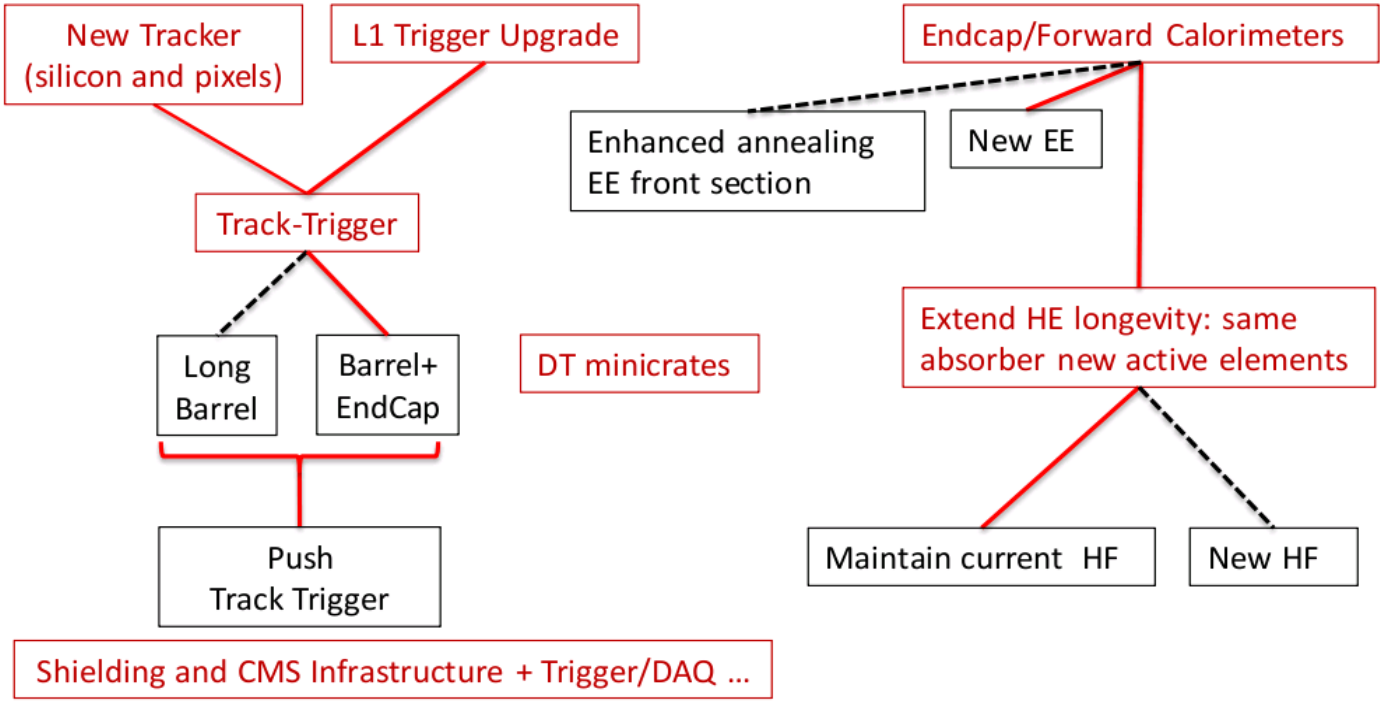
Scenario 0 : Longevity consideration - required upgrades



Main considerations:

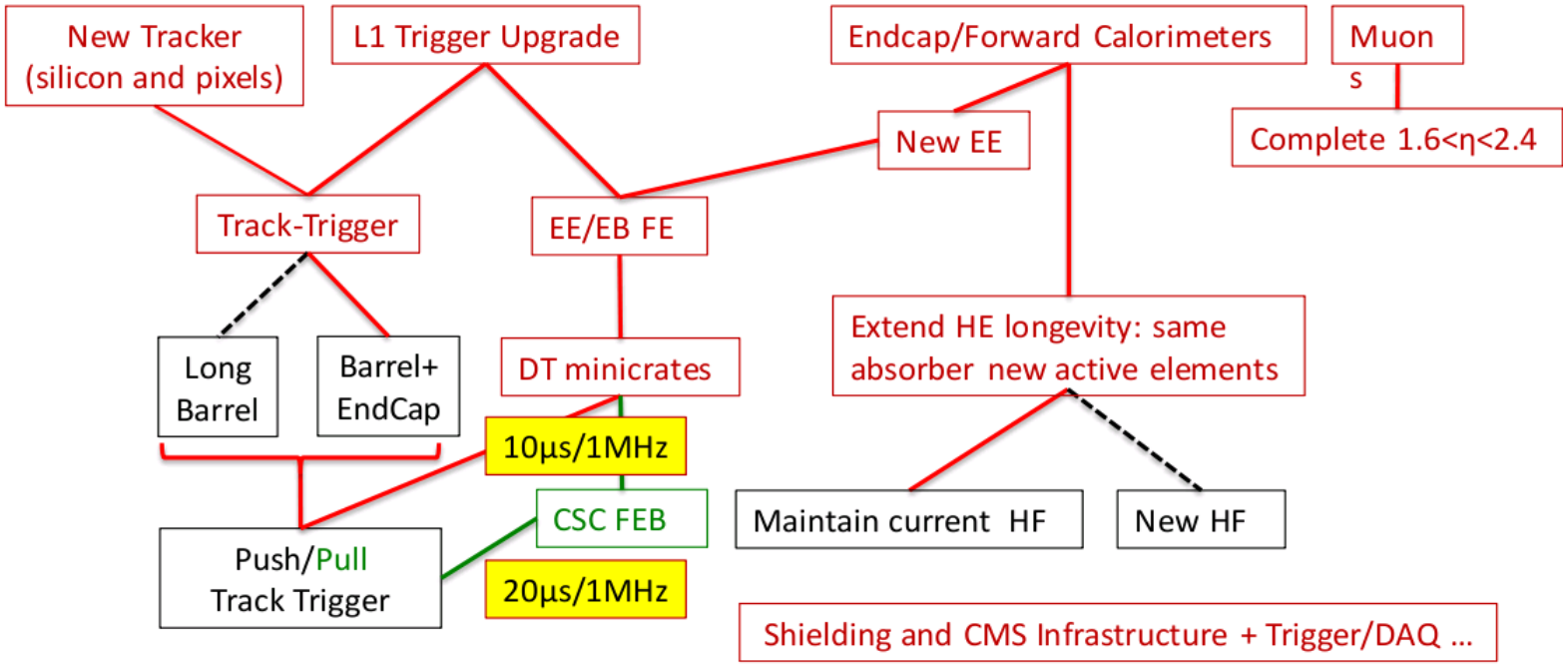
- Trigger entirely dependent on Track Trigger - Need to demonstrate Track trigger < 6.4 μs?
- FE electronics must operate past 2035?
- Tracker and/or Forward Calorimeter upgrades can be delayed/staged?

→ Longevity session Wednesday morning

→ Electronics/Online and TC session Wednesday afternoon D. Contardo, J. Spalding

Phase 2: Scenario 1

Scenario 1 : Improve L1 Trigger - increase rate and latency - add muons



Main considerations:

- Improved acceptance with lower Trigger threshold
- New EE is needed (can't only change EB FE)
- Opportunity for improved Calorimetry resolution and granularity
- New Tracker and EB FE in same LS (needs 26 months)
- New EE and HE in same LS (services)
- Open pull option for tracker, add pixel - ECAL crystal information at L1

LS ~ 3 years ?

→ Trigger session Friday morning

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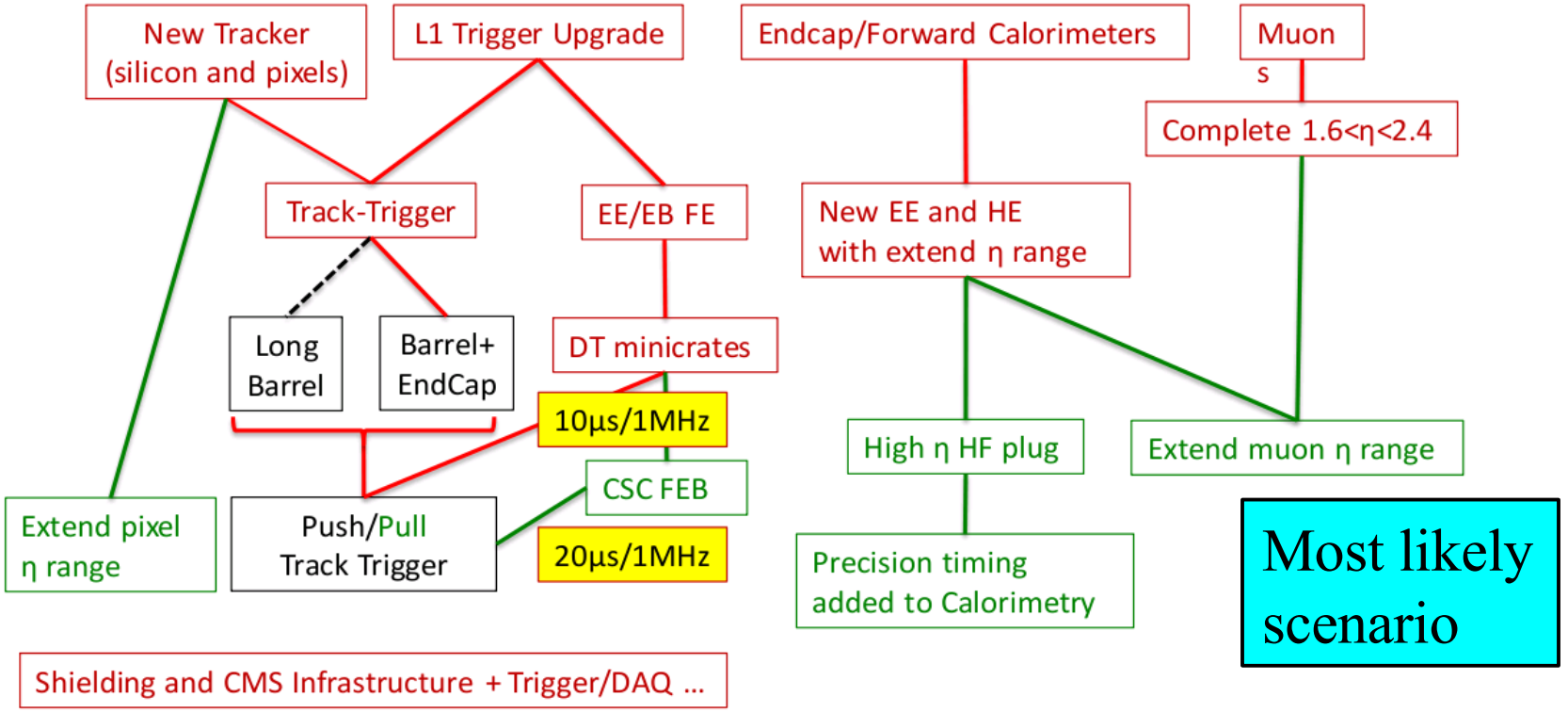
Phase 2: Scenario 2

Scenario 2: New Forward - extended η range - performance options



Main considerations:

- Increased acceptance/performance in forward region - need to understand background
- Option for pile-up mitigation with tracking extension and/or precision timing - can be staged
- Dismount EE/HE replace with new EE/HE assembled on surface

→ Forward Detector session Friday morning

LS ~ 3 years ?

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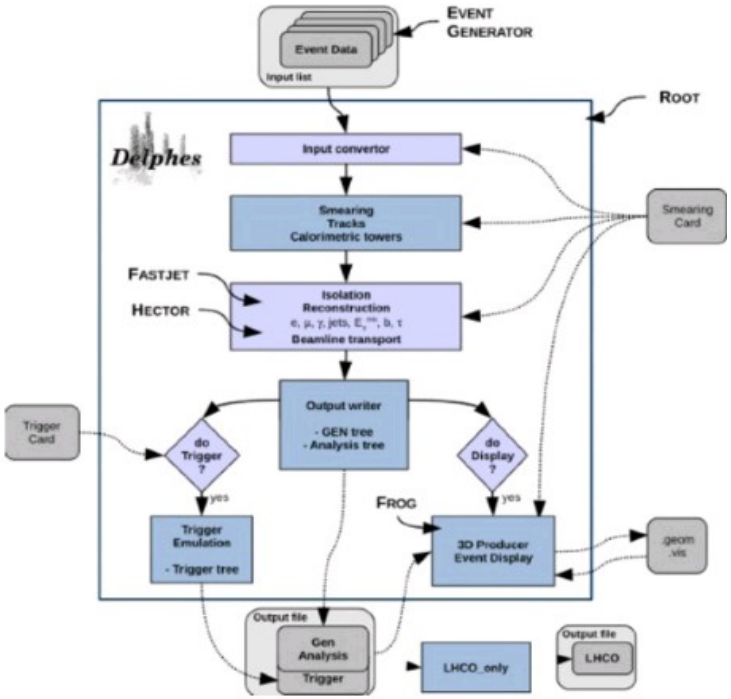
Simulation

Upgrade geometry/pileup scenarios

Delphes

- Overview on Delphes performance by Meena.
- Represents main feature of the detector. Validation with full simulation is essential.
- Fast simulation tool can be used to supplement full simulation samples.
- Main features of the detector can easily be adjusted. Setup for phase II studies.
- Easy use. Instructions from
  - delphes page
  - snowmass page
- Detector card based on mix of current and phase I detectors available. Includes PU settings.
- Interface LHE via physics and HEPMC or read GEN format directly



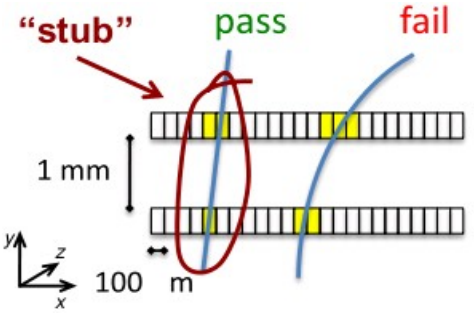
To first approximation we can think of it as a "Super" FastSim

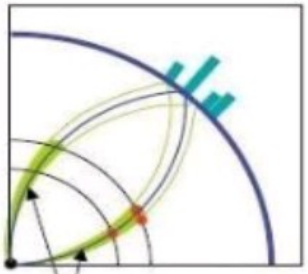
03/06/2013 Paolo Giacomelli - INFN Bologna 24

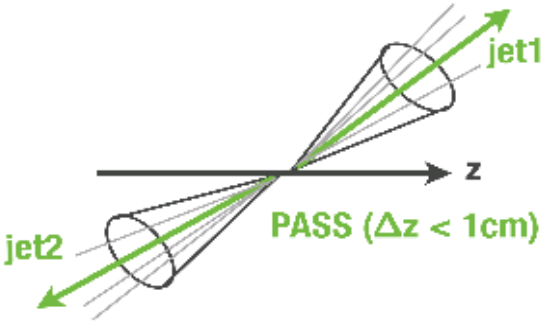
Monday, 3 June 13

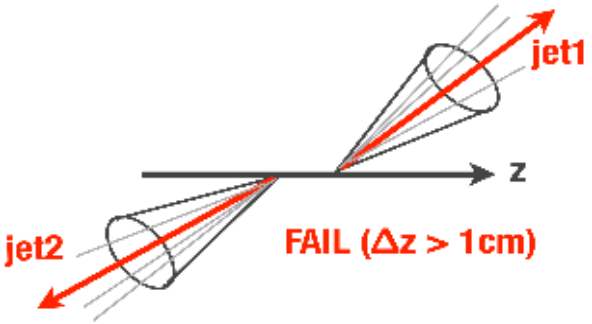
Triggering

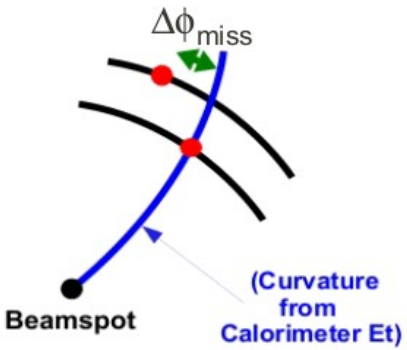
- Improve L1 by 10x to maintain physics performance, make full use of lumi
- Use information from tracker at L1 – EG/muon tracks, vertexing
- Use ECAL crystal information (requires replacement of ECAL FE electronics)
- New calorimeter trigger
- Purpose: reduce rates, increase efficiency
  - More study needed to determine effectiveness at rate reduction











Detector Longevity

ECAL

- Transparency

HCAL

- Radiation damage in high-eta HF
- New calorimeter proposal: “shashlik” design; PF

Muon

- GEM, glass RPC

Tracker

- Cooling (lifetime depends on temp)

ECAL Detector Longevity: IR Bleaching

Crystal transparency issue: crystal darkens with radiation, light collection efficiency goes down

- High temp annealing, optical/IR bleaching

In Situ Annealing plus Bleaching

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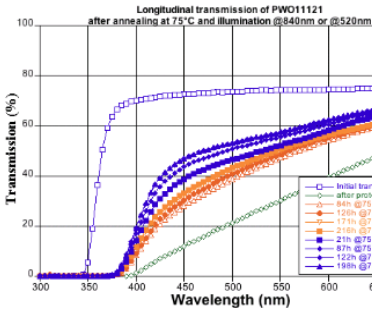
Partial Recovery with annealing at 75°C and optical bleaching

Maybe Technically Feasible to implement this

- Use the crystal cooling circuit for heating during technical stops (separate circuit for electronics)
- Remove ES and use space to plumb in optical fibers for bleaching

Using InfraRed (IR) 915 nm is preferred due to no effect on VPT so can be used during data taking



A. Singovski, E. Auffray CMS CR-2011

First Attempts at IR bleaching

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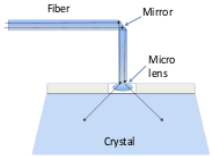
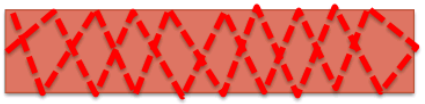
IR beam goes straight through crystal with little absorbtion and negligible recovery

Next: Change optics to make IR light bounce around crystal





A. Singovski

GIF++

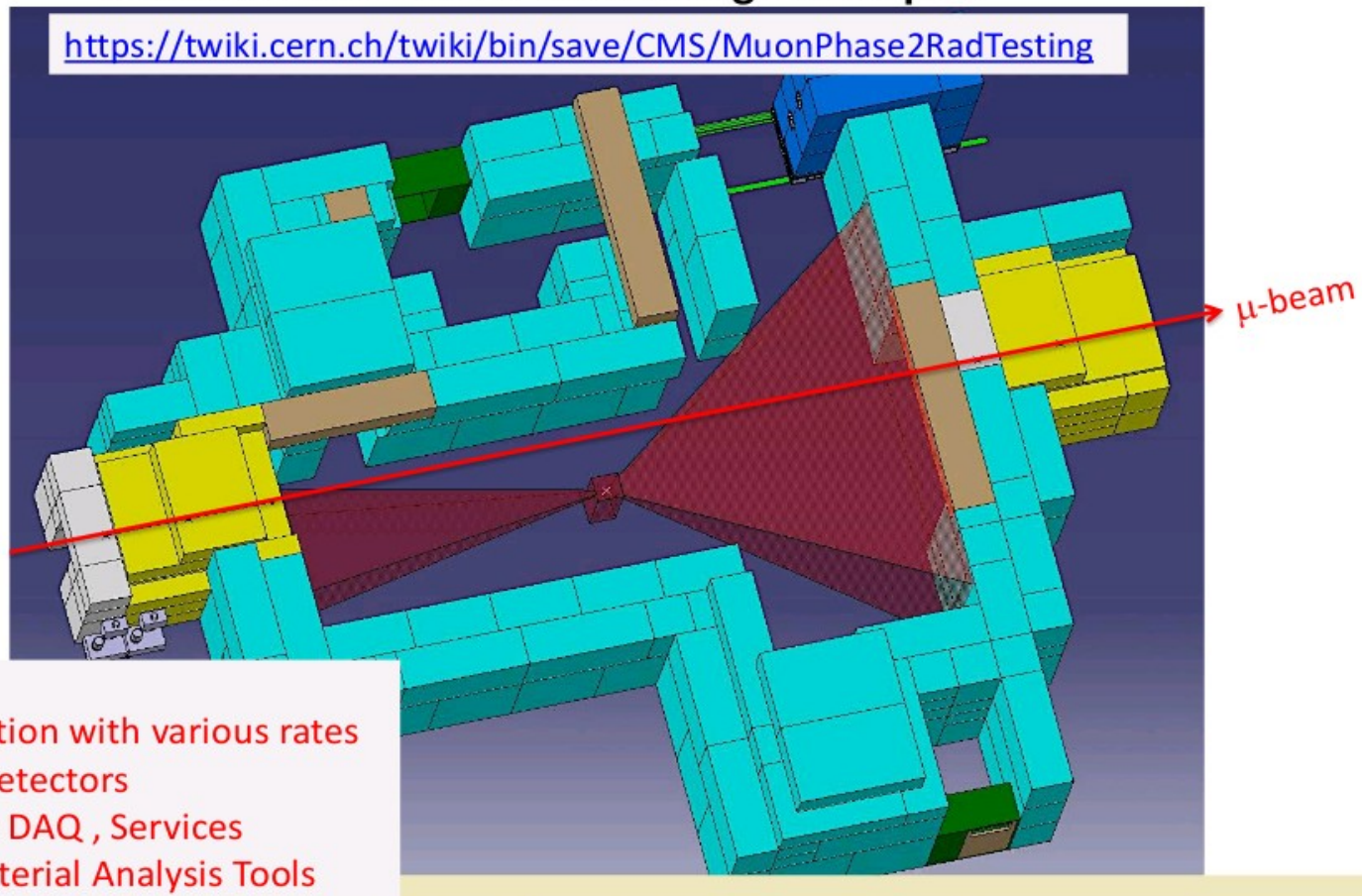
Physics Department
Detector Technology Group

GIF++
The new Gamma Irradiation Facility at CERN

READY : END OF 2014
(Beginning of 2015)

Common CMS Muon tests being developed

https://twiki.cern.ch/twiki/bin/save/CMS/MuonPhase2RadTesting



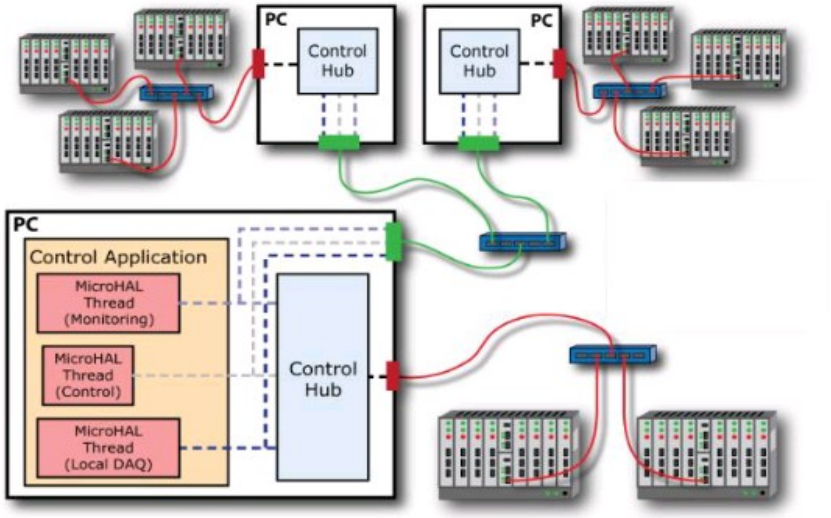
Beams
γ–Irradiation with various rates
Trigger Detectors
Common DAQ , Services
Gas / Material Analysis Tools

03/06/2013 DESY Upgrade Meeting June 3-7, 2013 16 A. Sharma

Electronics

IPbus (T.Williams)

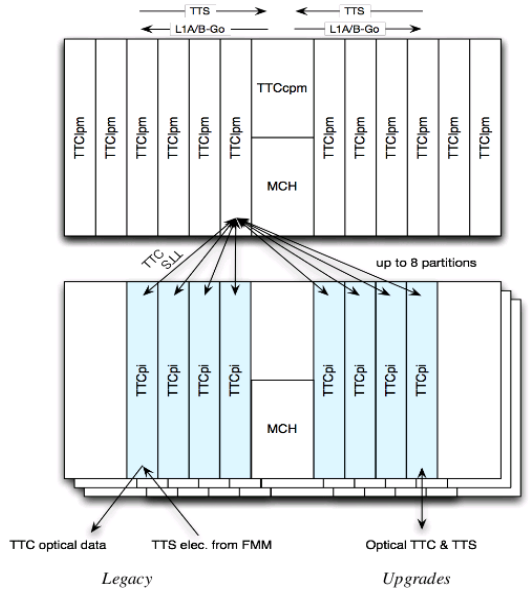
- An IP-based control protocol for µTCA/ATCA
- Originated in HCAL (v1.2) – J. Mans, E. Frahm, E. Hazen
- Now main responsibles are from L1 trigger
- Currently test setup running in 904

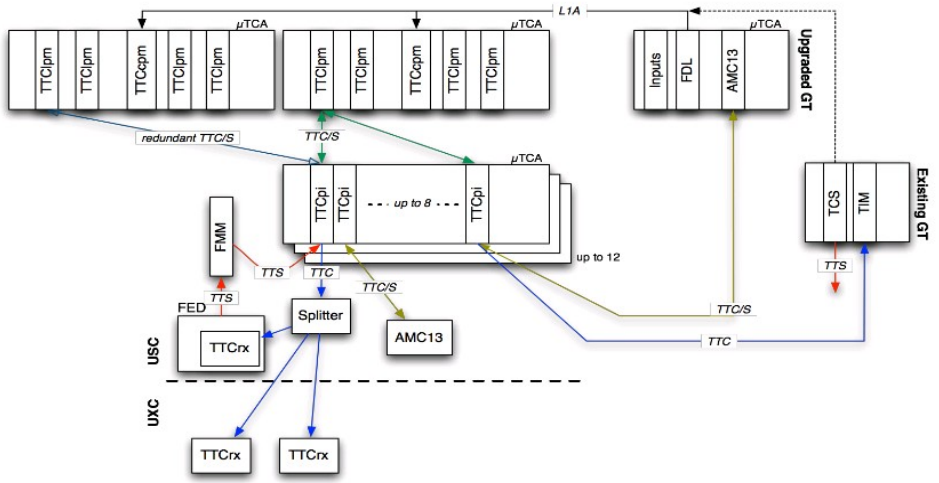


TCDS (M.Hansen)

TTC (Trigger Timing + Control) system will be upgraded to TCDS (Trigger Control and Distribution System) post-LS1

- Separate out functions of GT (global trigger)
  - Event selection (L1A) stays with GT
  - System control -> TCDS: trigger throttling, trigger rules, timing
- Increase to > 32 partitions – more flexibility
- -> RHU implements TTCrx functionality onboard





cpm – Central Partition Manager
lpm – Local Partition Manager
pi – Partition Interface

LumiDAQ (C.Schwick)

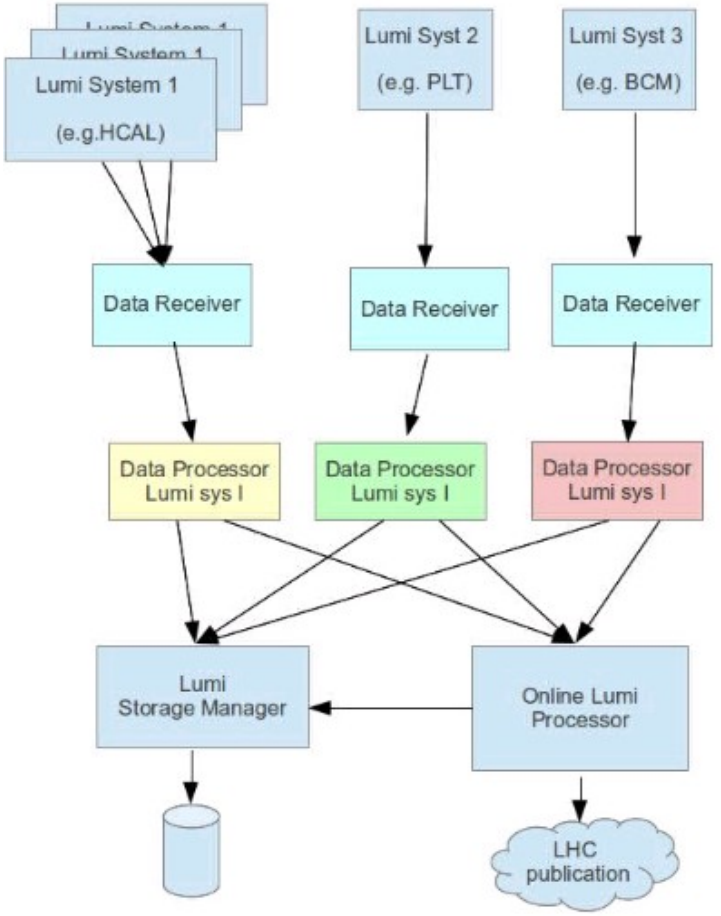
DAQ system for luminosity post-LS1

- Needs to be separate from regular CMS run control
- Will include more lumi subsystems e.g. BCM1F

CMS run vs “luminosity run”

- Needs to run whether or not CMS running
- Working on how to correlate lumi runs and central CMS DAQ runs for purpose of lumi

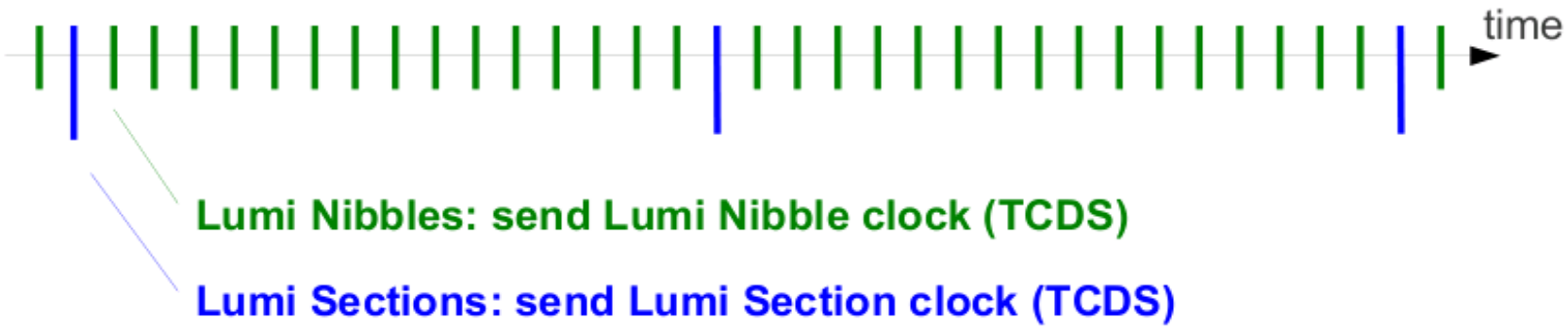
Will also publish BCM1F background values



LumiDAQ recent focus

Synchronization

- Necessary if one lumi subsystem drops out: take back in on-the-fly
- Use current count of Lumi Nibbles and Lumi Sections
  - LN: ~1s (RHU histogram boundaries) = X orbits
  - LS: ~20s (data unit for physics) = Y lumi nibbles
  - Run begins with LS 1, LN 1
- Details still being worked out



Looking forward

Meetings: Snowmass (July), ECFA (Oct.)

Prepare white paper

- DELPHES physics studies: Higgs, BSM, SM
- General upgrade justifications, projections

Joint document with ATLAS

Have technical proposal for Phase 2 by RRB Oct. 2014

Consideration: ATLAS has public notes with just a few authors... also for CMS?

Document summarizing Upgrade Week will be circulated in near future


CMS


DESY

Phase 2 Scenarios Summary

Highlights of upgrade options

- Tracking trigger
- Extend muon system
- Replace calorimeter (HF/EE)
- Extend pixel/tracker