Francesco Lanni – ATLAS, Marcello Mannelli – CMS
Alberto Valero (ATLAS), Arno Straessner (ATLAS)
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David Silvermyr (ALICE), Frederic Machefert (LHCb)

ECFA WORKSHOP
CALORIMETRY WORKING GROUP
INTRODUCTION AND OVERVIEW
PHYSICS REQUIREMENTS

The HL-LHC and Phase II

- Both Alice and LHCb are planning major upgrades in LS1 and LS2, and their physics program is not directly impacted by the luminosity upgrade of the HL-LHC
- Limited scope of upgrades and/or consolidation foreseen for LS3
  - ALICE is considering the possible addition of a new Forward Calorimeter
  - The LHCb ECAL requires substituting some of the modules closest to the beam, with existing spares

The HL-LHC and Phase II

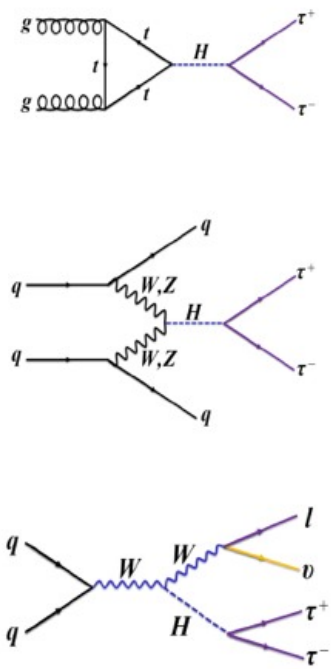
For ATLAS and CMS the HL-LHC enables a Key set of Major Physics Goals for Phase II:

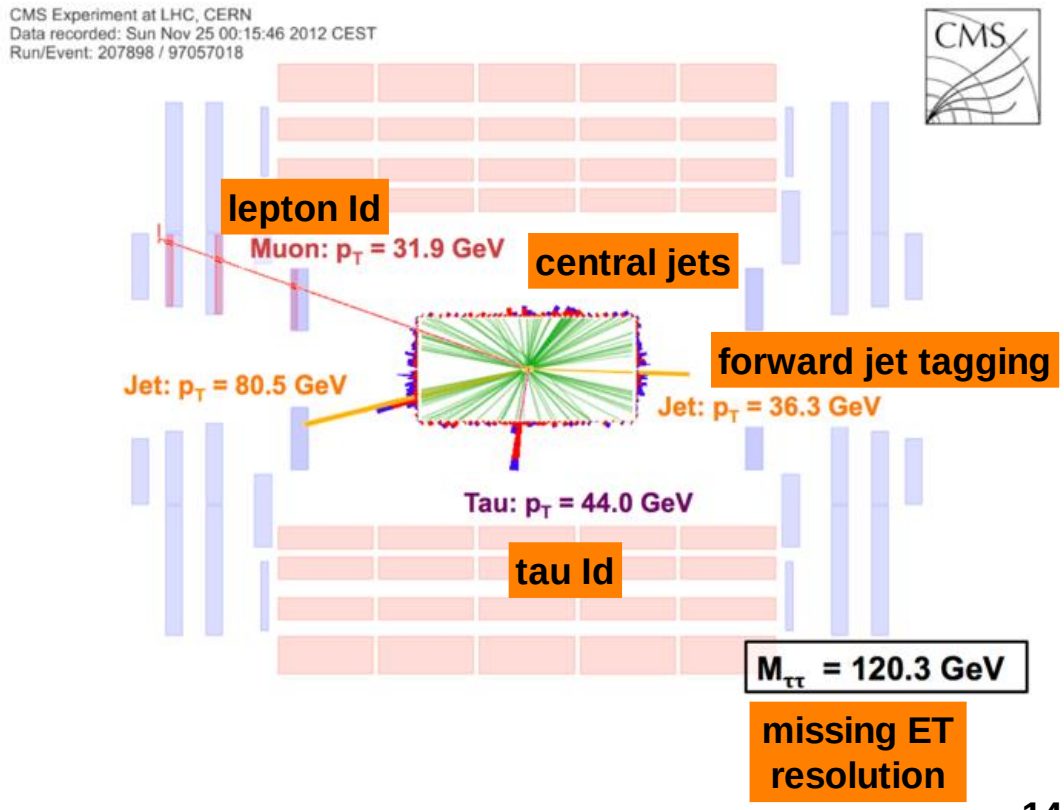
- Detailed characterization of the Higgs and EWK Symmetry Breaking Sector
- Extend direct searches for BSM physics, cover small cross-section production and/or difficult final state signatures, characterize any new BSM physics processes
- Extend indirect searches for BSM physics through precision measurements of very rare SM processes

The HL-LHC and Phase II

VBF H → ττ

Tracker, Calorimeter, Muon performance & coverage are critical in order to exploit HL-LHC physics potential

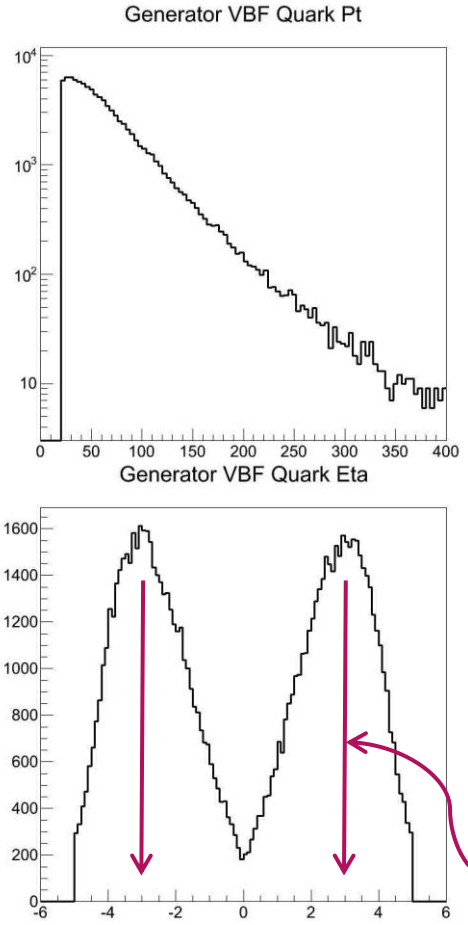


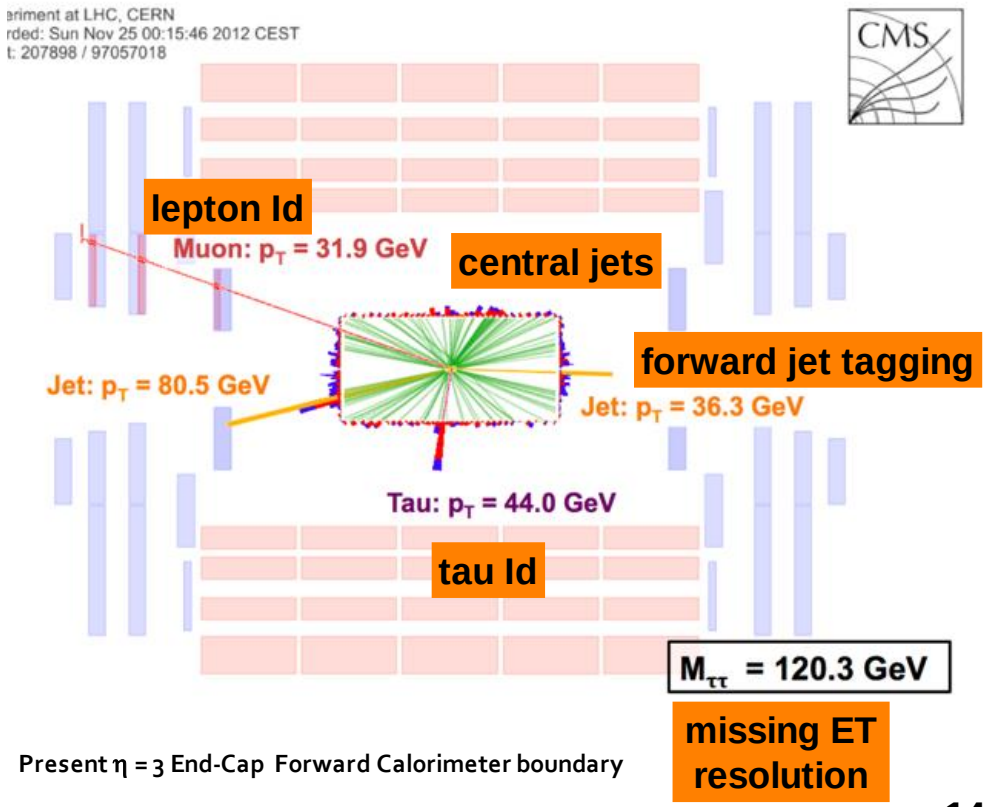


The HL-LHC and Phase II

Tracker, Calorimeter, Muon performance & coverage are critical in order to exploit HL-LHC physics potential

VBF H ➜ ττ





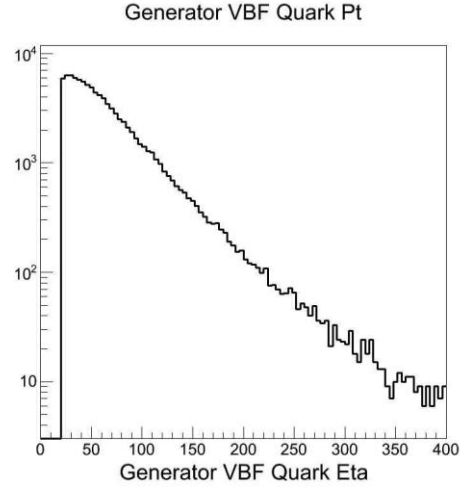
Present η = 3 End-Cap Forward Calorimeter boundary

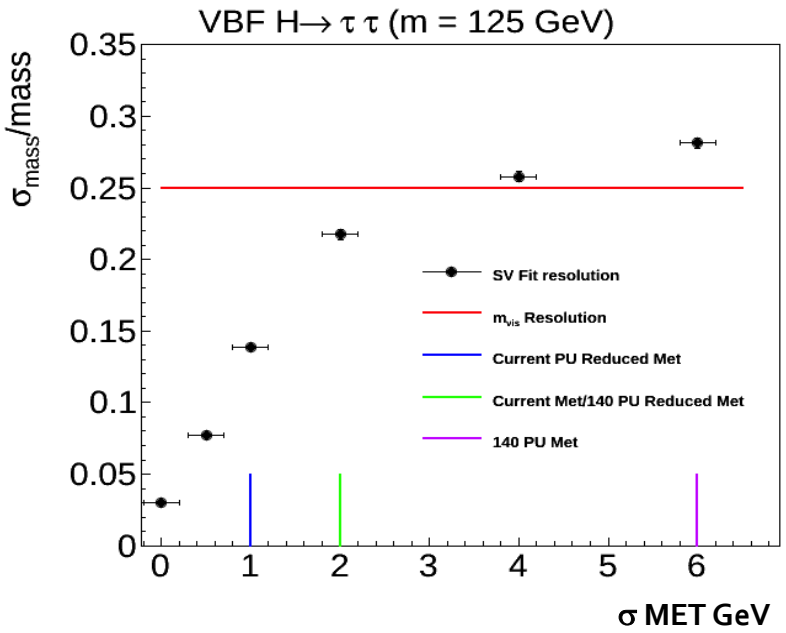
14

The HL-LHC and Phase II

VBF H → ττ

Tracker, Calorimeter, Muon performance & coverage are critical in order to exploit HL-LHC physics potential





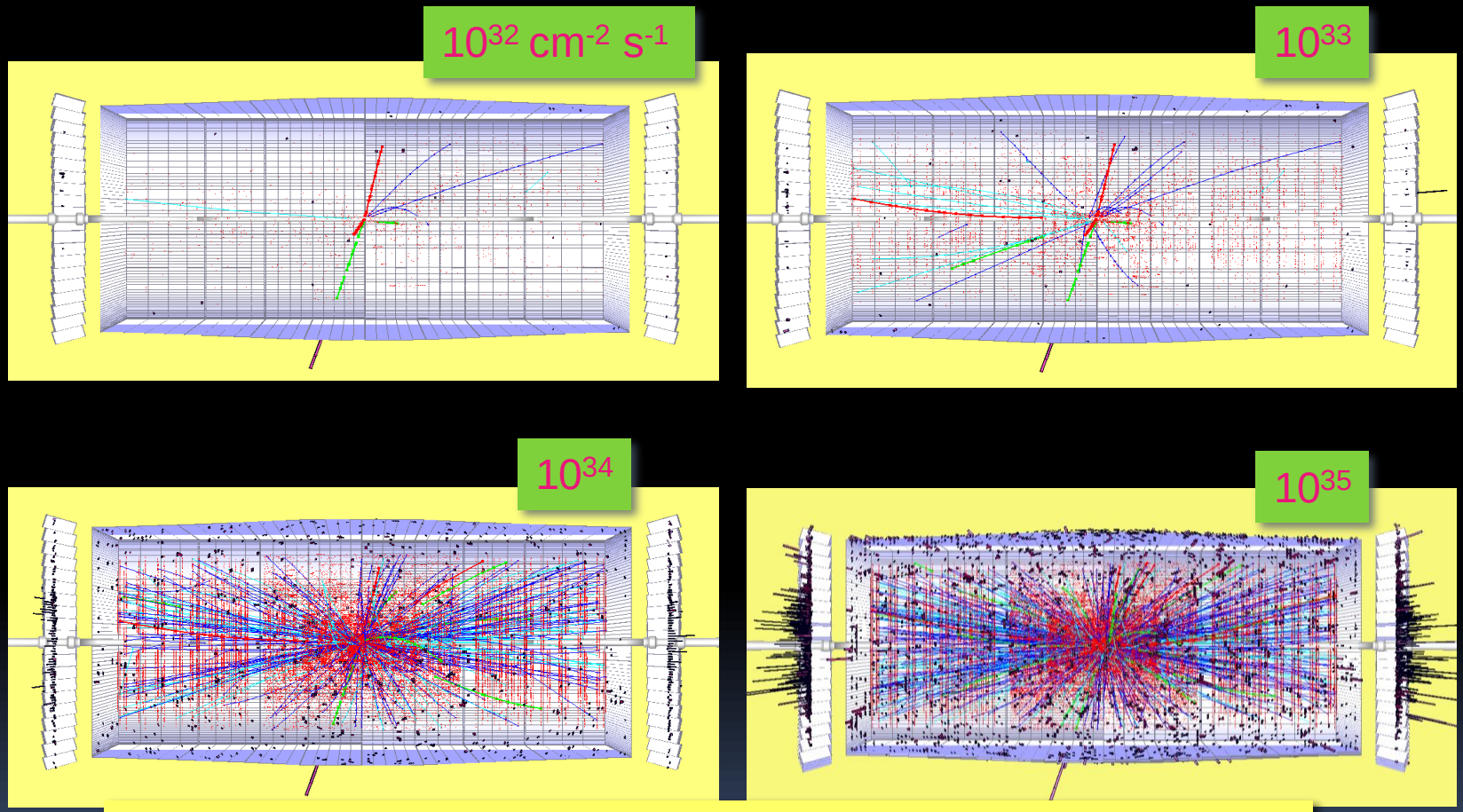
Present η = 3 End-Cap Forward Calorimeter boundary

$M_{\tau\tau}$ = 120.3 GeV

missing ET resolution

14

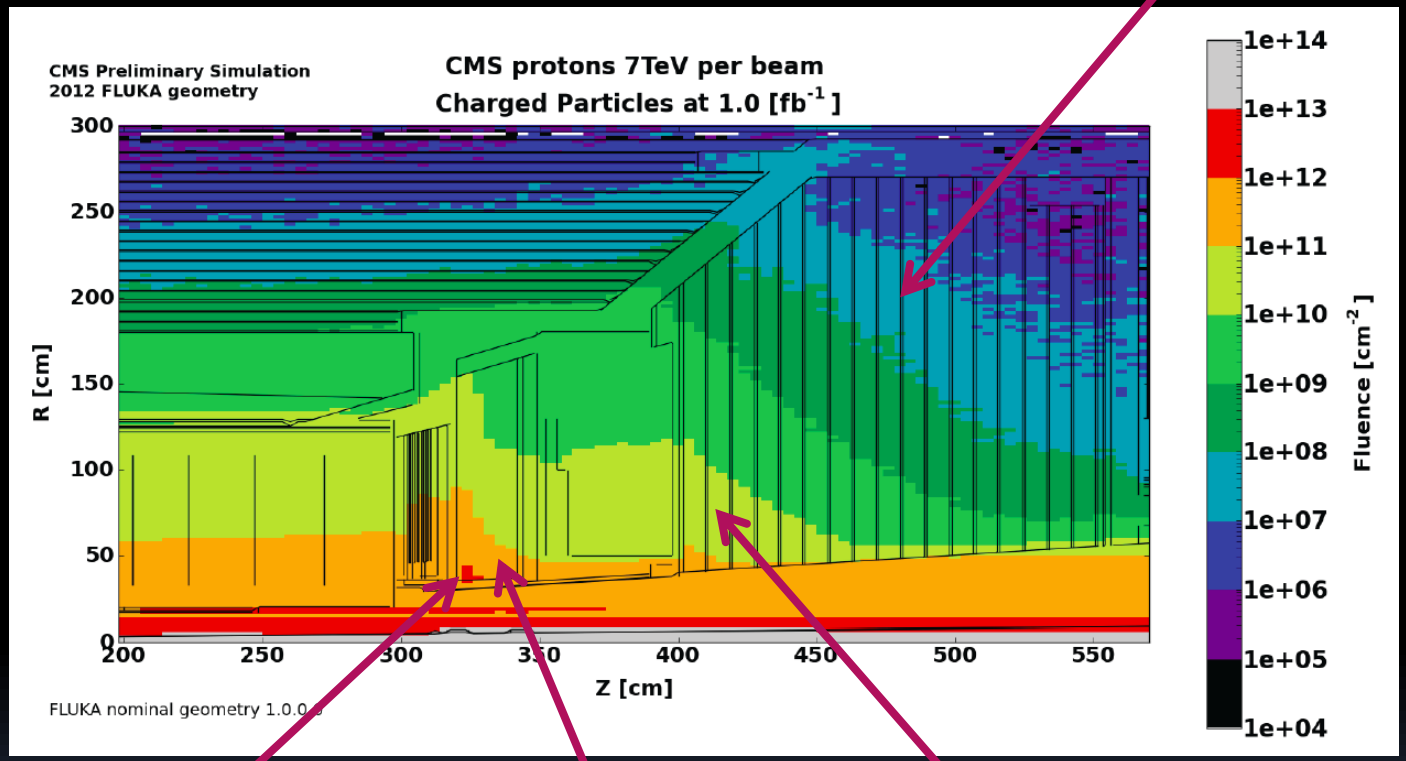
HL-LHC Pile-Up Environment and Detector Performance Challenges



At HL-LHC ATLAS and CMS face new challenges, for Tracking and Triggering, as well as Precision Calorimetry, particularly in the End-Cap and Forward regions

HL-LHC Radiation Environment and Detector Longevity Challenges

500 Hz/cm²



50 MHz/cm²

5 MHz/cm²

500 kHz/cm²

At 5×10^{34} we get 1 fb^{-1} every 20,000 secs (5 ½ hours!).

Longevity, Trigger requirements & Calorimeter Electronics Upgrades

- More selective triggers required to maintain efficiency for EWK sector & 125GeV Higgs boson
  - High granularity Calorimeter information is required for efficient and selective triggers
    - Making extensive use of detailed topology of clusters and events
    - Providing improved Calorimeter Trigger primitives for e/γ/τ/Jets, matching with Track Trigger, isolation, etc
- Compared to the present systems, longer latency is needed to accommodate sophisticated Trigger algorithms, and increased Read-Out bandwidth is required to include full range of BSM signatures

Longevity, Trigger requirements & Calorimeter Electronics Upgrades

- To address these requirements, both ATLAS and CMS are planning electronics upgrades to allow full 40MHz data transfer from the Calorimeter detectors

- These will also ensure Calorimeter electronics systems longevity through Phase II
  - *The longevity ATLAS Lar Hadron End-Cap Calorimeter (HEC) cold electronics is under evaluation: replacing this this would necessitate opening of the cryostat*

Longevity, Performance & Calorimeter Detector Upgrades

- The ATLAS & CMS Barrel calorimeters are sufficiently rad-hard to operate through Phase II

- The ATLAS End-Cap LAr calorimeters are intrinsically radiation hard
  - The LAr FCAL may suffer due to the high instantaneous rates, and may need to be augmented, or replaced

Longevity, Performance & Calorimeter Detector Upgrades

- The performance of the CMS End-Cap ECAL and HCAL would substantially degrade at HL-LHC, and both must be replaced

- A targeted R&D program is underway to meet the challenges of replacing the CMS End-Cap calorimeters
  - Different approaches are being evaluated, and some options are under study

CMS Calorimeter Upgrades: Approaches and Options under study

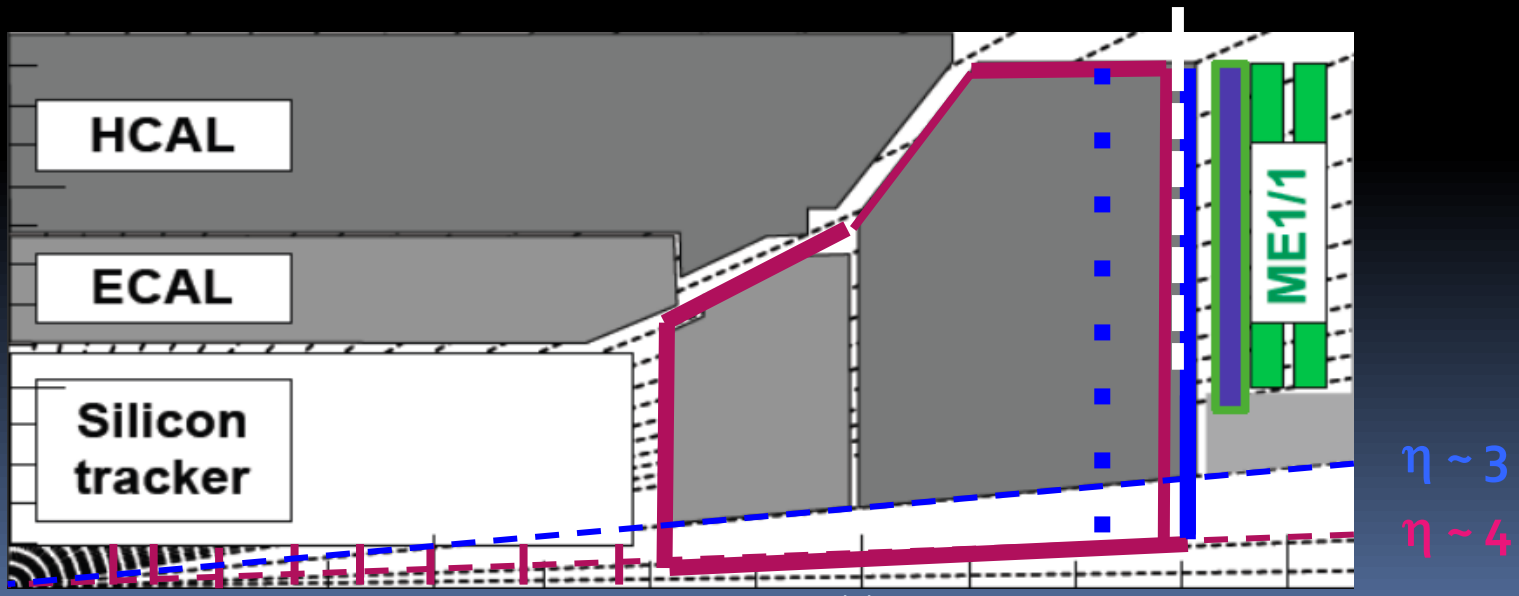
- First Approach:
  - Maintain the present tower-like geometry, develop more radiation tolerant solutions for End-Cap Ecal and End-Cap Hcal, possibly with finer granularity

- Alternative Approach:
  - Consider Integrated Calorimeter with potential for improved performance and/or reduced costs

Option I Under Consideration: Extended End-Cap Calorimeter Coverage

Replace EE and HE with a new End-Cap Calorimeter system, matched to the extended Tracker coverage to $\eta=4$

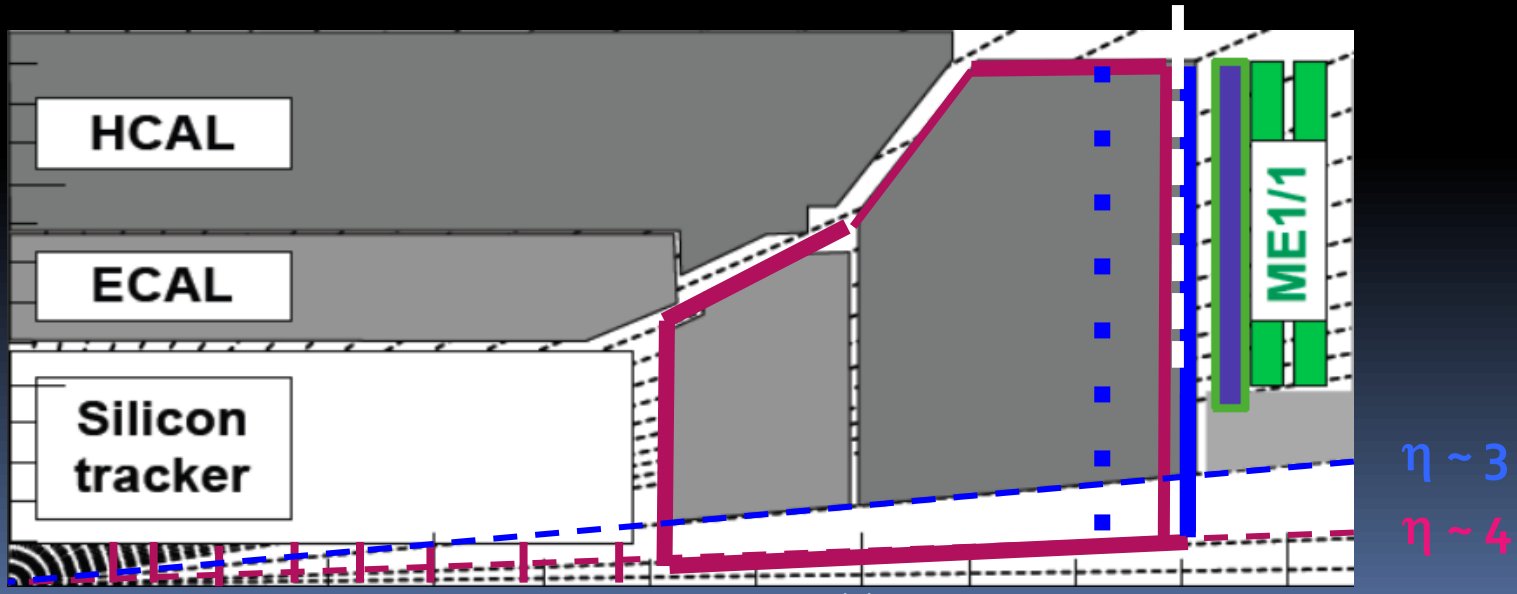
- An opportunity for
  - Optimized Particle Flow, lepton, Jet/MET reconstruction
  - Uniform detector response spanning the peak of VBF jets ($\eta=4$)
  - Extended Muon coverage, in shadow of new EE/HE ($\eta<4$)



Option I Under Consideration: Extended End-Cap Calorimeter Coverage

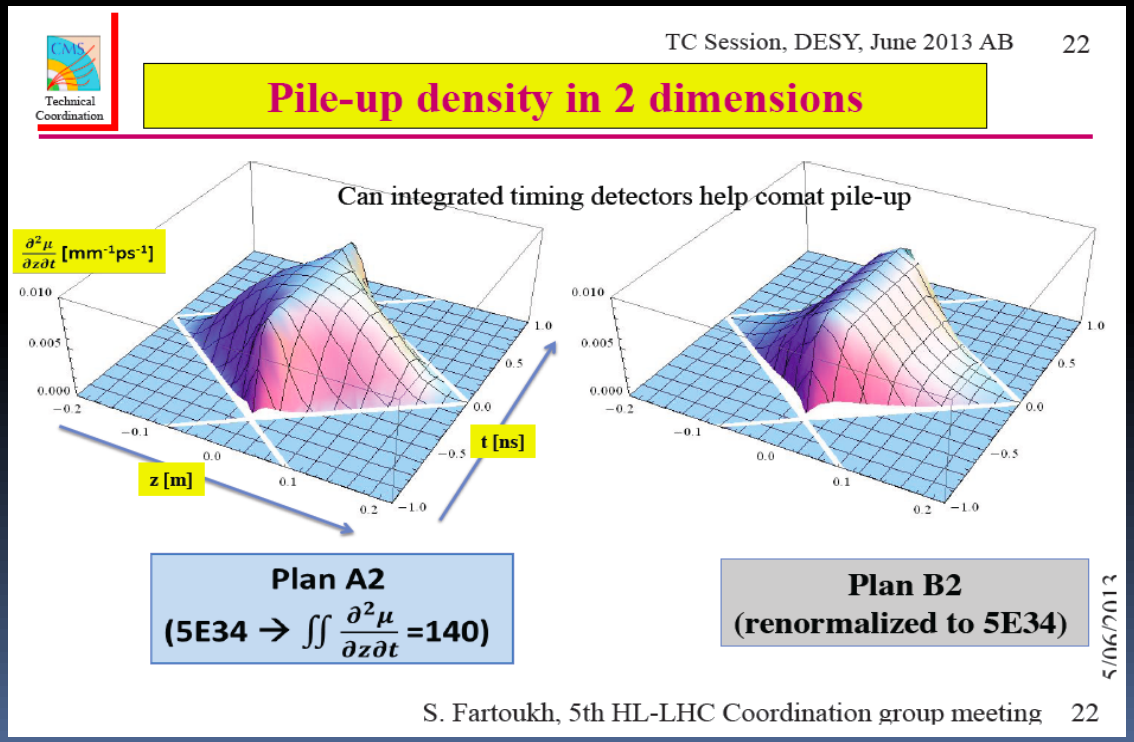
Replace EE and HE with a new End-Cap Calorimeter system, matched to the extended Tracker coverage to η=4

- Challenges include
  - Performance in very high pile-up particle density
  - Much increased fluence and radiation hardness requirements
  - Potential increase of neutron flux, especially in Tracker volume
  - Integration issues (low β quads, opening/closing of CMS, etc)



Option II Under Consideration: Precision timing for Calorimeter Pile-Up mitigation

- 10~20ps resolution, associate charged and neutral clusters to reconstructed vertices, filter out pile-up clusters
  - Feasibility and physics benefits under study
  - Depends on both Longitudinal and Time distribution of collisions, for which various scenarios are under evaluation



Agenda

- 20’ Introduction and Overview of Physics Goals and Calorimeter Requirements
  - Marcello Mannelli
- 30’ Calorimeter Electronics: Longevity issues and/or new requirements and resulting upgrades
  - Arno Straessner
- 40’ Calorimeter Detectors: Longevity issues and/or new requirements and resulting upgrades
  - Pawel de Barbaro
- 10’ Summary and Conclusions
  - Francesco Lanni

Backup

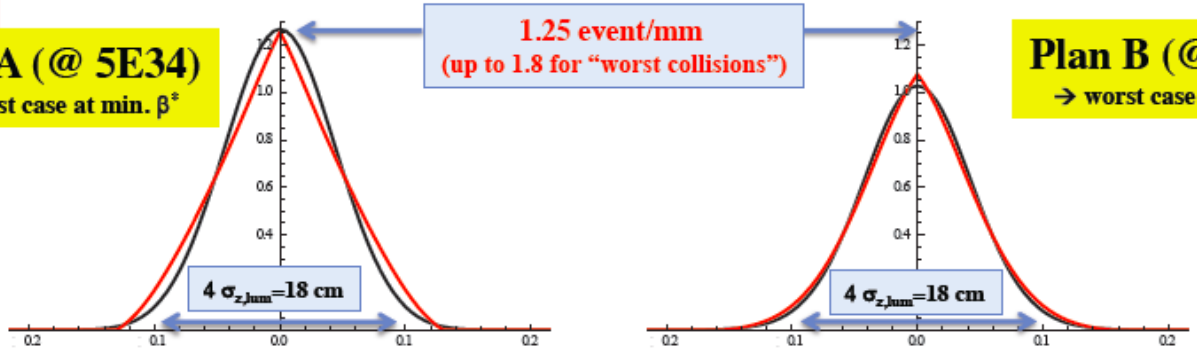
Under Consideration: Calorimeter Pile-Up Mitigation

Detailed comparison between Plan A & B

Plan A (@ 5E34)
→ worst case at min. β^*

1.25 event/mm
(up to 1.8 for "worst collisions")

Plan B (@ 4E34)
→ worst case at min. β^*

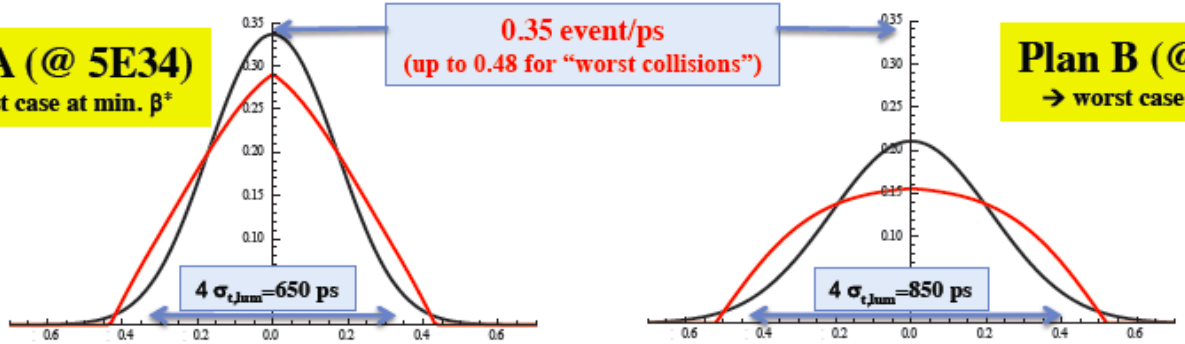


Line pile up density [mm^{-1}] for Plans A & B as a function of z [m] w.r.t. the IP
→ At constant r.m.s. bunch length, rectangular (in red) does not help w.r.t. Gaussian (in black) longitudinal distribution

Plan A (@ 5E34)
→ worst case at min. β^*

0.35 event/ps
(up to 0.48 for "worst collisions")

Plan B (@ 4E34)
→ worst case at min. β^*



Time pile up density [ps^{-1}] for Plans A & B as a function of t [ns] w.r.t. the BPTX signal
→ At constant r.m.s. bunch length, rectangular (in red) helps by 15-20% w.r.t. Gaussian (in black)
→ The time density is reduced by 2 from Plan-A (w/o HH RF system) to Plan-B (with HH RF system)

S. Fartoukh, 5th HL-LHC Coordination group meeting 21

5/06/2013