High Granularity Timing Detector (HGTD)

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- In the framework of the “Large Eta Task Force” of the ATLAS collaboration
- Extensions or improved instrumentation in the forward region at eta > 2.5
- Improvement of the phase-II ATLAS detector with much better pile-up rejection at HL-LHC
- A benefit for number of physics channels for signatures with forward jets or multiple objects and more efficient background suppression
  - Standard Model, Higgs boson VBF processes, H-> 4 leptons, ttbar background rejection for H->WW (improved missing energy transverse resolution, extended b or c tagging)
  - SM physics with VBF processes, same sign WW
  - WZ final states

Upgrade scenarios

Extend ITK tracker to $2.5<\eta<4$: different pixel layouts (extended IBL, disks, rings, pixel granularity,...)

sFCal $3.1<\eta<4.9$: FCAL1 with better transv. granularity and reduced pulse length

Trigger w/ fwd tracking:
- L0/L1 capabilities
- vertex information

Muon spectrometer options for $2.7<\eta<4.0$:
- 1 pixelated tag chamber before EC toroid
- 2 chs (before/after EC toroid) +1.5T warm toroid

Segmented timing-preshower detector in front of EMEC/FCAL in $2.5<\eta<4$ (MBTS location):
($\sim 100\mu m; \sim 10 ps$)


Timing preshower detector
Multi-Channels Plate (MCP)
Mini-FCAL

Si-W calorimeter

A Silicon HGTD detector inspired in Calice
HGTD in the gap between the LAr barrel and end-cap cryostats

- Gap occupied by ITk services, ITk end-plate and MBTS
- Reconfiguration is possible
- Envelope of Delta z = 70 mm available
Calorimeter cell noise

- Degradation of the performances because of the pile-up conditions at the HL-LHC
- Increase of the total noise in individual readout channels

Expected total noise energy (electronic + pile-up) of the cells at different eta for an average number of interactions $\mu=30$ and $\mu = 200$

- From lower to higher pile-up scenarios, significant increases
- High level of noise in the EMEC and FCAL
High Granularity **Timing** Detector

- Capability to identify the vertex origin of forward jets
- Pile-up vertices produced at different $z$ positions:
  Particles from different vertices arrive at different times (interactions occur at different times)
- Crab-kissing: a novel colliding scheme to extend the spatial pile-up density profile and to reduce the spread of the time density of hard scatter interactions

Run1: very small separation for signal and pile-up due to the large time spread of collisions relative to the $z$ spread of the bunch

Crab-kissing: significant sharpening of the time distribution for hard scatter particles, maintaining a large spread for pile-up particles

HGTG ATLAS based on CALICE

ATLAS
• measurement: t and E
• 4 layers in depth (z)
• Granularity: 5mm x 5mm
  • option: mix with 1cm x 1cm
• Same basic structure
• No absorber
  • option: absorber

Weaker constraints:
• 4 layers in 6cm ~1.5cm per layer:
  Chip+PCB+Glue+Wafer=3.225mm,
  leaves 1cm for cooling and
  absorber (eg tungsten 3mm 1X0)

Harsher constraints:
• Cooling of sensors -20deg
• RadHardness of FE electronics
• RadHardness of Glue
  (measurements foreseen in
  2015-2016)
• 40MHz
• Time measurement

ILD
• Measurement: E (and t)
• 30 layers
  • Absorber: tungsten

  • 30 layers in 18cm ~0.6cm per layer
  • includes tungsten absorber

  • Cooling of electronics (passive)
  • Zero suppression/Power pulsing
  • 5Hz 1ms bunchtrain
Signal:
• Large MIP signal (roughly 10-15 for CALICE)
• Occupancy (rough estimate): ¼ (at \( \eta = 4 \))
• Intrinsic timing resolution \( \sim 150\text{ps per RO for S/N=25-30} \)
  • 4 measurements per track?
  • Per jet/area?
  • Add absorber to increase signal? Which material? Impact on energy resolution?
  • LGAD sensors?
• Granularity variation from 5mm to 10mm?

Readout:
• 5mm x 5mm pads:
  • 38x4x2 ASUs
  • 304k channels (=1.5*LArg)

Digital flux:
• 3ASUs=3072channels : 4Tb/s
• Zero suppression: ¼ (not sufficient)
• Reduction to Gb/s:
  • More than 1 link per ASU
  • Lvl1 reduction of 500-1000 (buffering?)
  • Local clustering?
Sketch of an implementation in ATLAS

Preserve basic CALICE structure

Slabs CALICE-like:
• 2ASUs
• 3ASUs

Alternative:
• Single PCB
• Pro: less interconnections
• Con: planarity

Support structure (attached to cryostat)
• Material?
• Alveola?
• Direct mounting?

R = 110 mm, \( \eta = 4.1 \)
R = 600 mm, \( \eta = 2.4 \)

Ratio 1:2
Center at 34 cm 34 cm
R_{extreme} = 702 mm
Time-line and milestones for the implementation of the HGTD
Expressions of interest

Expression of interest for ATLAS
September 4th ATLAS meeting on High Granularity Timing Detector

• Didier Lacour (LPNHE):
  • assembly of ASUs
  • characterization of wafers and ASUs: geometry and electric I(U)
• Daniel Fournier, Laurent Serin, Dirk Zerwas (LAL), Dominique Breton (SERDI-LAL):
  • FE electronics
  • digital readout electronics
  • assembly of Slabs
• Christophe de la Taille (Omega):
  • FE electronics
  • in charge of the architecture of the CMS HGCAL readout → similarities with HGTD

Expression of Interest for the ATLAS HGTD project

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