High Granularity Timing Detector (HGTD)

Didier Lacour (LPNHE Paris) - Dirk Zerwas (LAL Orsay)
members of the ATLAS and Calice collaborations

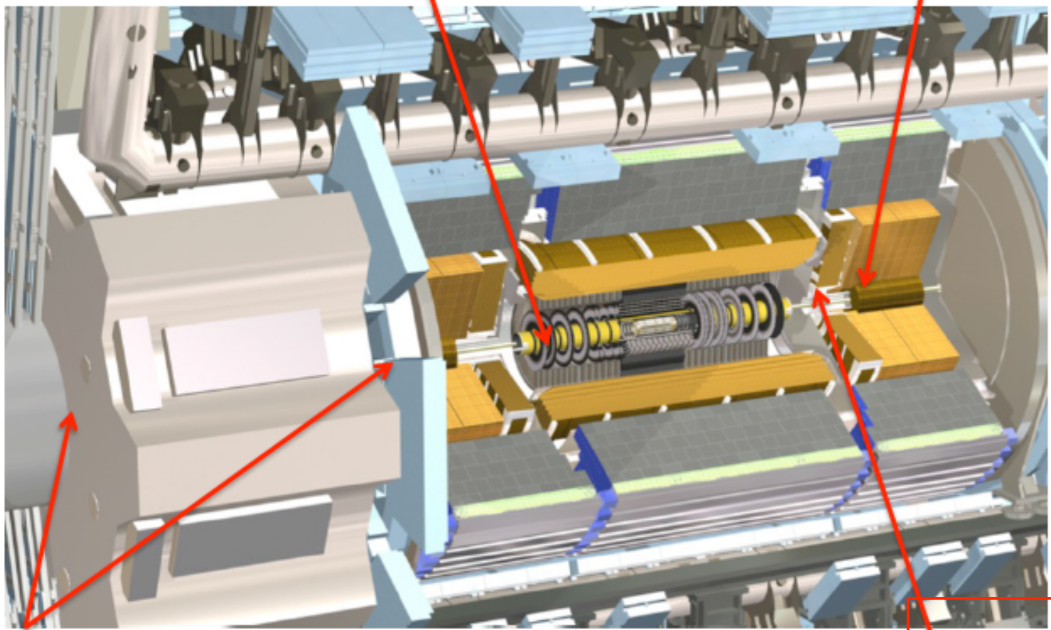
- In the framework of the “Large Eta Task Force” of the ATLAS collaboration
- Extension or improved instrumentation in the forward region at eta > 2.5
- Improvement of the phase-II ATLAS detector with much better pile-up rejection at HL-LHC
- A benefit for number of physics channels for signatures with 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

Reference: ATL-UPGRADE-INT-2015-001 31st May 2015

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): (~100μm;~10ps)

Timing preshower detector

Multi-Channels Plate (MCP)

Mini-FCAL

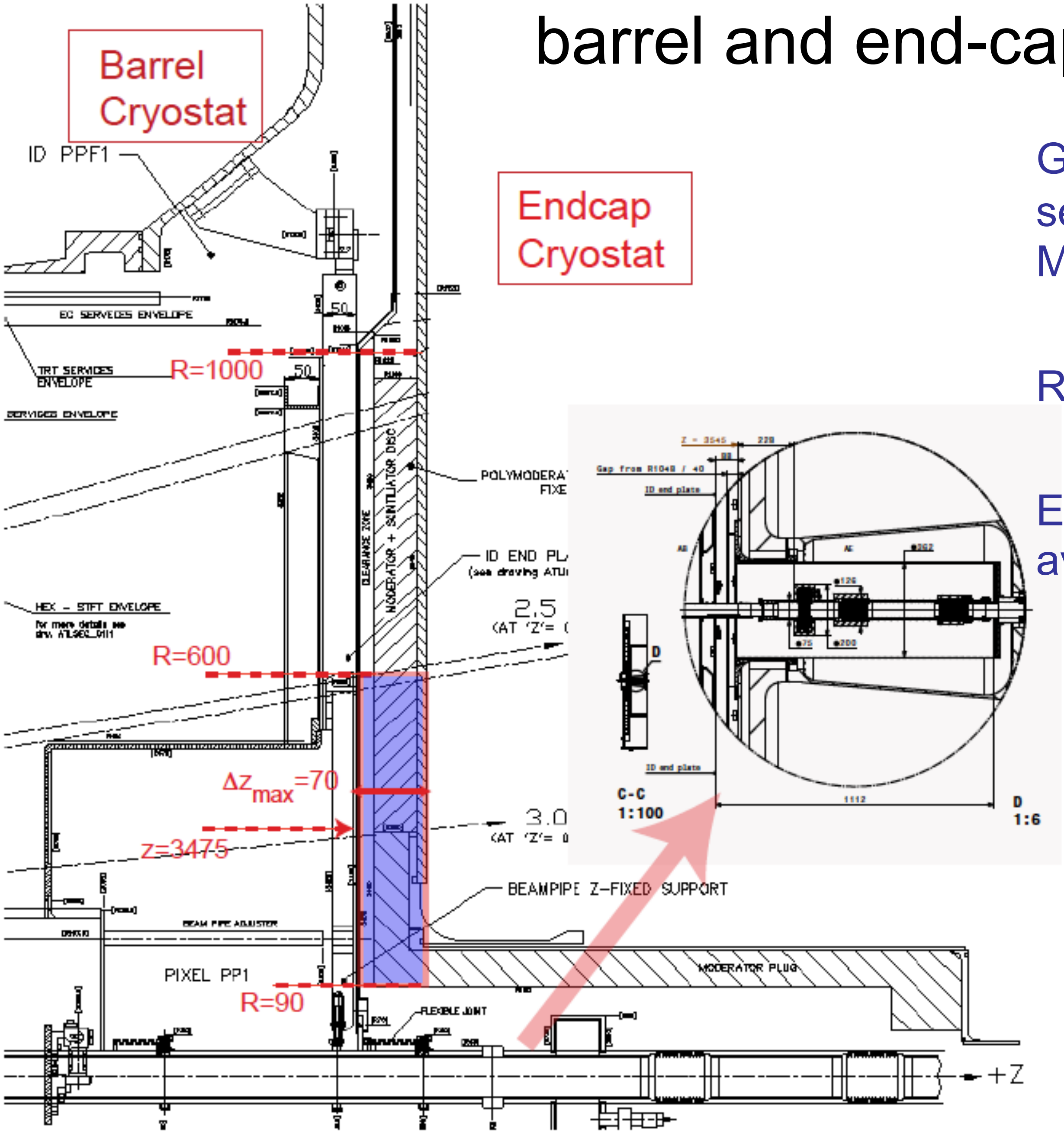
Si-W calorimeter

…

A Silicon HGTD detector based on Calice

Reference: ATL-UPGRADE-INT-2015-001 31st May 2015

HGTD in the gap between the LAr barrel and end-cap cryostats



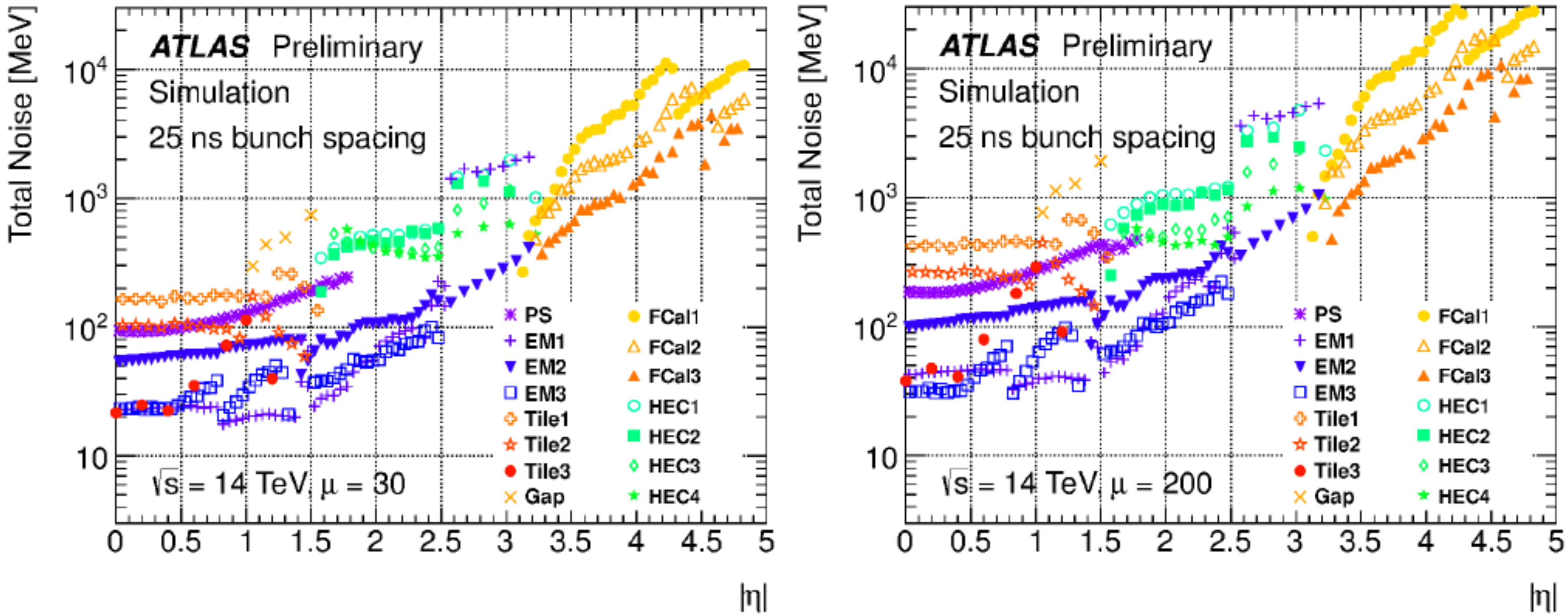
Gap occupied by ITk services, ITk end-plate and MBTS

Reconfiguration is possible

Envelope of Delta z =70 mm available

Calorimeter cell noise

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

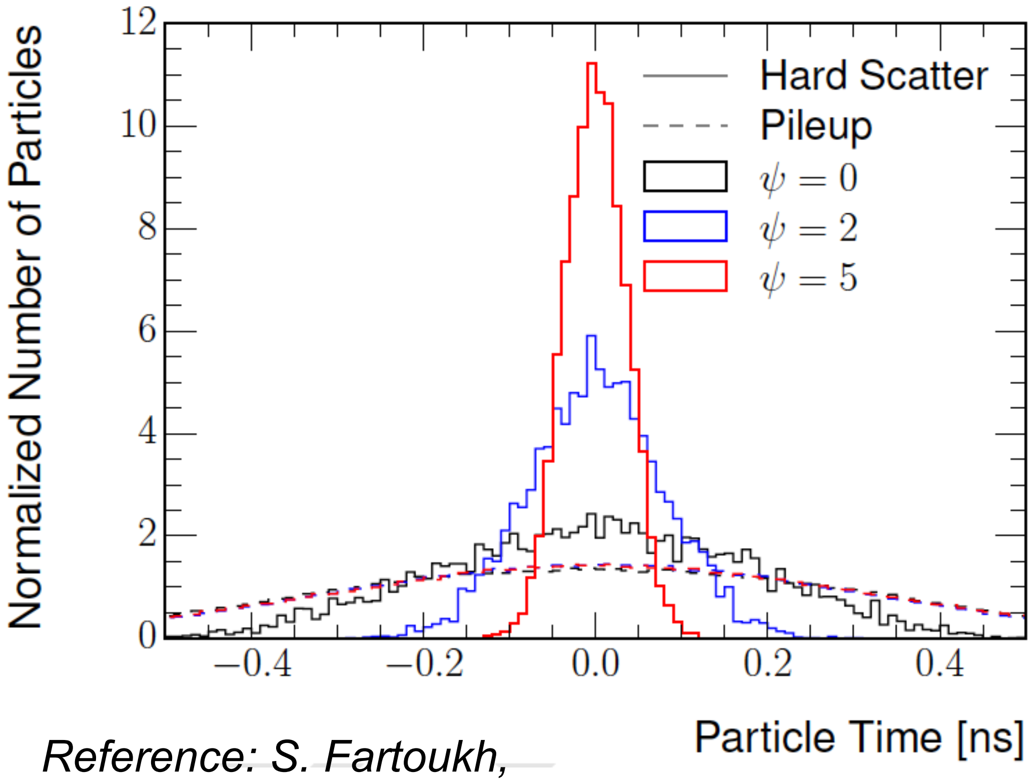


Expected total noise energy (electronic + pile-up) of the cells at different eta for an average number of interactions mu=30 and mu = 200

- 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
- 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 (solid and dashed black lines): 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

Reference: S. Fartoukh,
Pile up management at the high-luminosity LHC and introduction to the crab-kissing concept, Phys. Rev. ST Accel. Beams 17,111001 (2014).

HGTD 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
- Options: No absorber/Absorber

Weaker constraints:
- 4 layers in 6cm ~1.5cm per layer: Chip+PCB+Glue+Wafer=3.225mm, leaves 1cm for cooling and absorber (tungsten 3mm or Pb 5.6mm 1X0 in support structure)

Harsher constraints:
- Cooling of sensors -20deg
- RadHardness of FE electronics
- RadHardness of Glue (measurements foreseen in 2015-2016)
- Time measurement (order 50 ps)
- Smaller peaking time
- 40MHz

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 ~150 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)

Data throughput:

- 3 ASUs=3072 channels : 4Tb/s
- Zero suppression: ¼ (not sufficient)
- Reduction to Gb/s:
  - More than 1 link per ASU
  - Lvl1 reduction of 500-1000 (buffering on ASU →redundancy)
  - Local clustering?

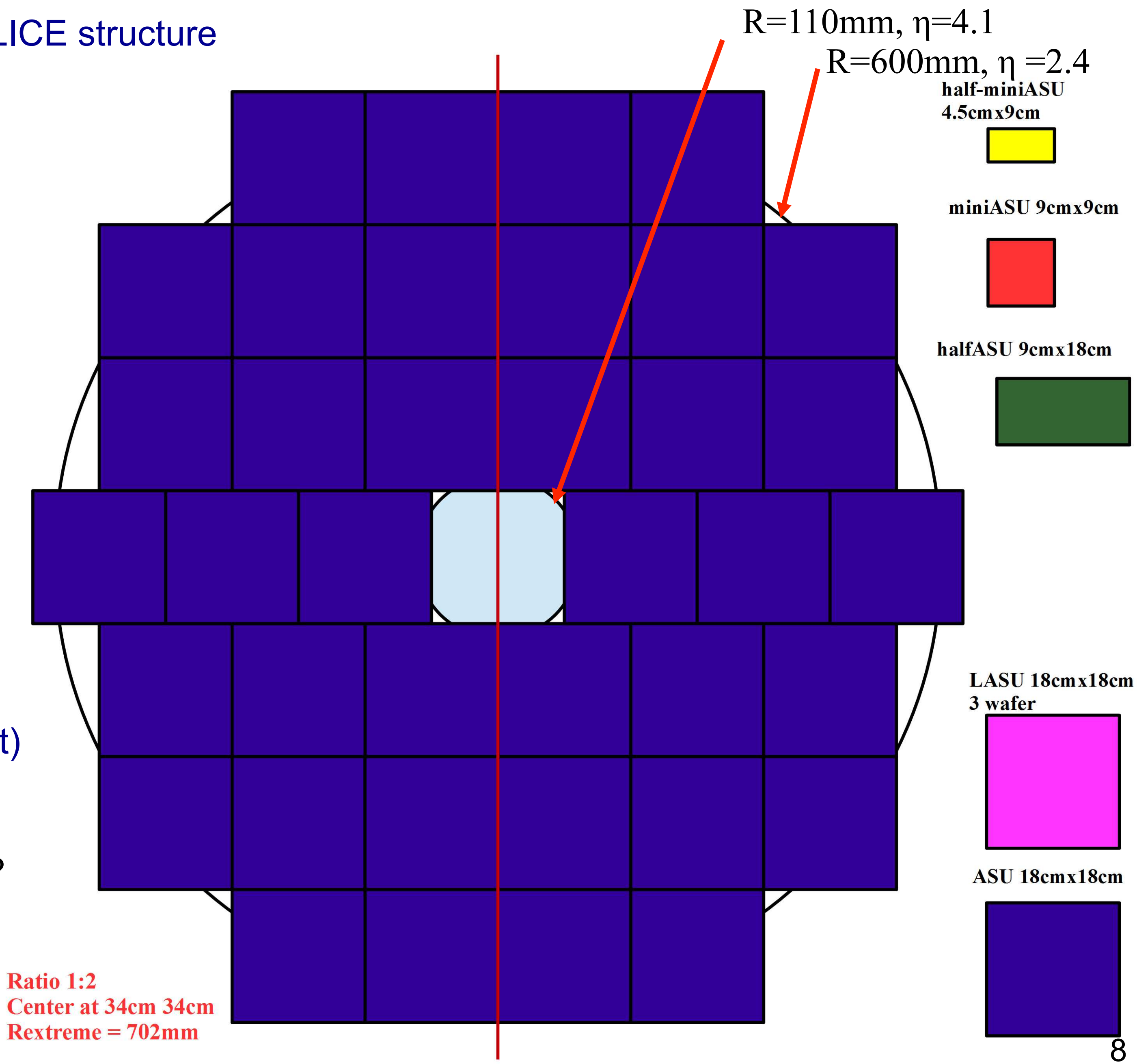
Sketch of an implementation in ATLAS

Preserve basic CALICE structure

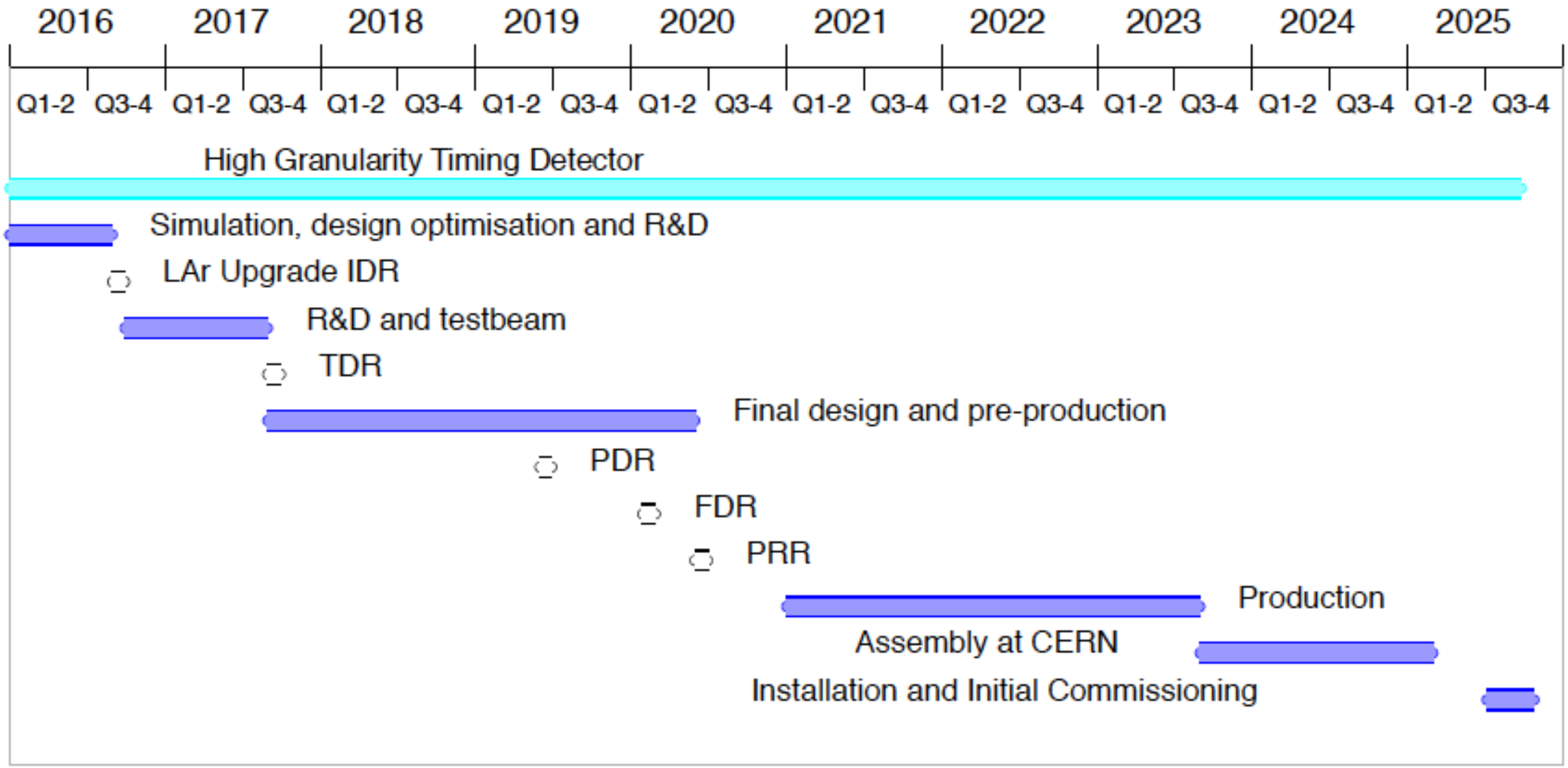
Slabs CALICE-like:
- 2ASUs
- 3ASUs

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

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



Time-line and milestones for the implementation of the HGTD



Expressions of interest

Text for IN2P3 circulation

Détecteur haute granularité avec très bonne résolution en temps pour la région 2.4 < η < 4

D. Fournier[i], D. Lacour[ii], C. de La Taille[iii] L. Serin[i] , D. Zerwas[i]

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

Expression of Interest for the ATLAS HGTD project

D. Breton[i], D. Fournier[i], D. Lacour[ii], C. de La Taille[iii] L. Serin[i], D. Zerwas[i]

Possible contributions

- 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