Mechanics and granularity considerations of a Tile hadronic calorimeter for FCC hh barrel

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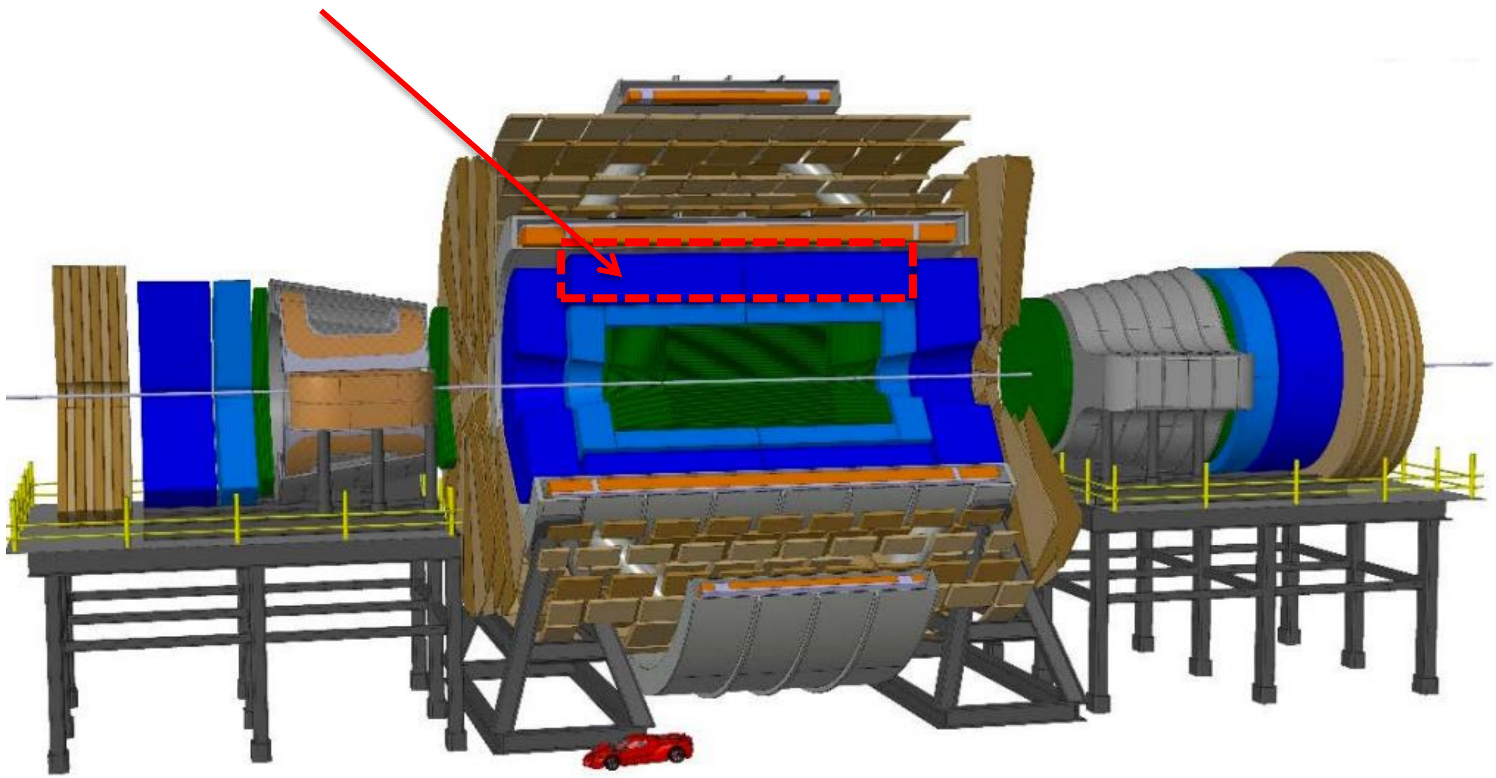
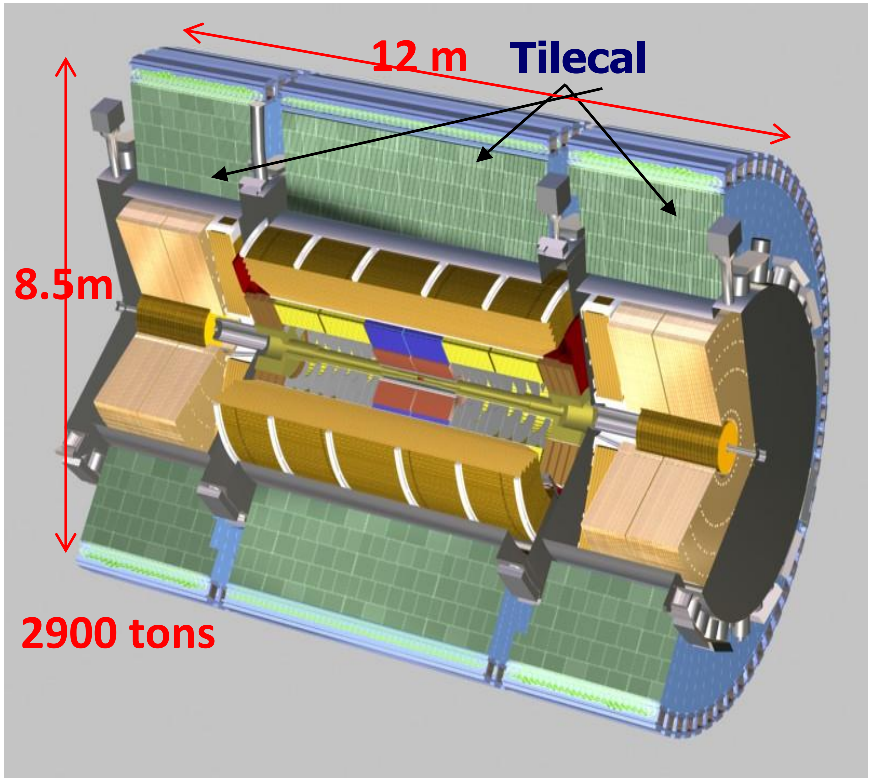
- The ATLAS Tile barrel had. Calorimeter concept using Si-PMTs as readout was presented in the February 2015 FCC-hh detector Workshop :

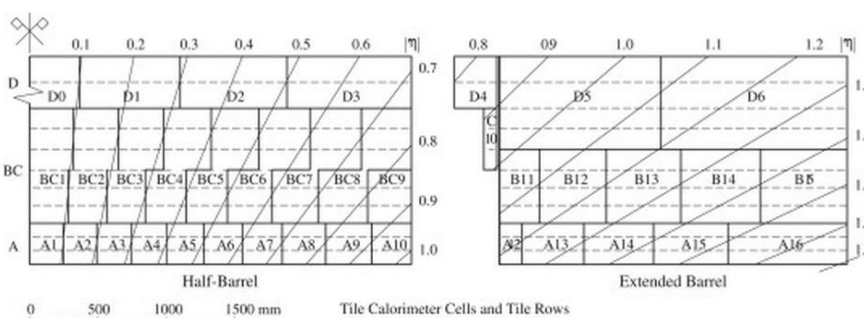
https://indico.cern.ch/event/358198/session/2/contribution/1/3/attachments/713312/979278/ANA_TALK_FCC_scint-1.pdf

- For FCC-hh optimisations are needed at the level of mechanics, optics, electronics readout, …
- Today will discuss barrel HCAL mechanics and granularity matters



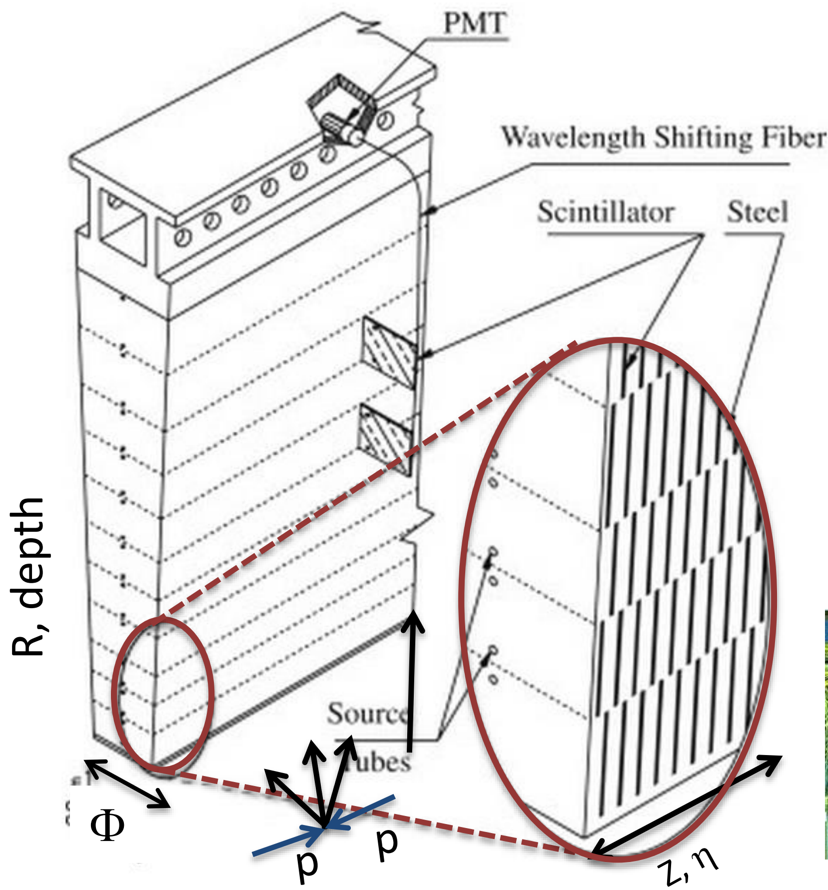
ATLAS Tile hadron calorimeter (|η|<1.7)

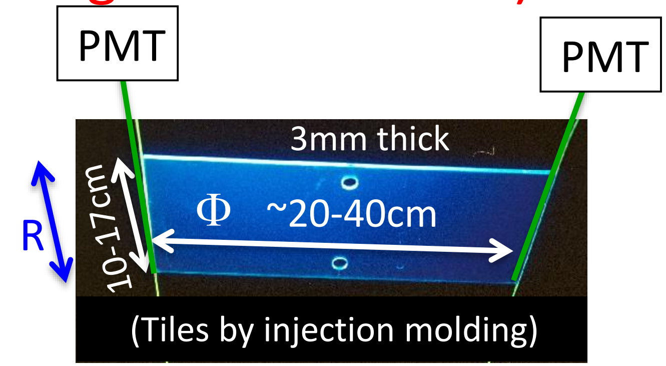




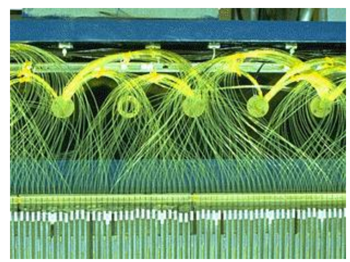
- Scint. Tiles; fibres ∥ to incoming particles at $\eta=0$
- Steel/Tiles: = 4.7 : 1 (λ = 20.7 cm)
- Active cells volume: ~ 372m3
- ~ 620k fibres ; 40k Tiles
- 10 k channels
- 7.7 λ at $|\eta|=0$; (9.7 λ with the em LAr calo)
- Transversal granularity $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
- Longitudinal segmentation: 3 layers
- e/h = 1.33
- Pion resolution (test beam):
  - $\sigma_E/E \sim 52\%/\sqrt{E} \oplus 5.7\%$ (7.9 λ)
  - $\sigma_E/E \sim 45\%/\sqrt{E} \oplus 2\%$ (9.2 λ)
- target (with e.m. LAR) at ATLAS/LHC:
  - Jet $\sigma_E/E \sim 50\text{-}60\%/\sqrt{E} \oplus 3\%$
  - Containment ~ 98% TeV hadrons, jets

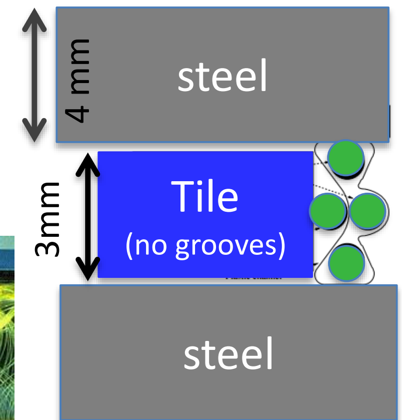
Today's ATLAS Tilecal optics granularity (but merged at readout…)





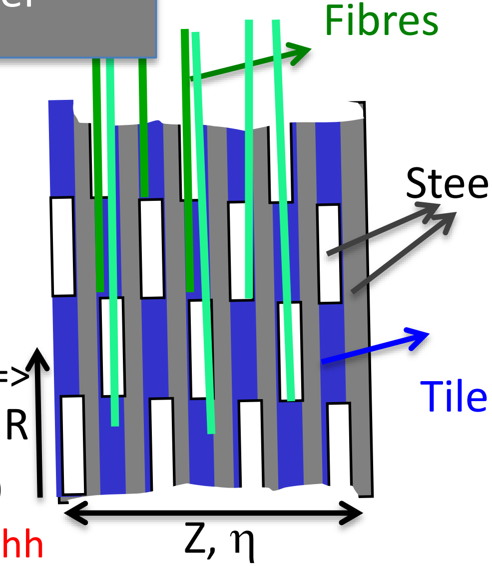
Fibre bundles
(at outer radius)





Fibres start at different R and go radially out =>

- No ϕ cracks
- R segmentation
- PMTS out Radius



Δη: 3mm tiles every 9-18mm in Z->0.0007<Δη<0.008

ΔR: 11 tiles and 8 fibres in R -> 8-11 layers with 1λ<ΔR<0.5 λ

ΔΦ: 20 cm tiles-> Δϕ=0.1 (with dual fibre readout)

In total ~ 620k fibres and 40k tiles ; but ~80-300 Tile-fibres couplings in 1PMT =>

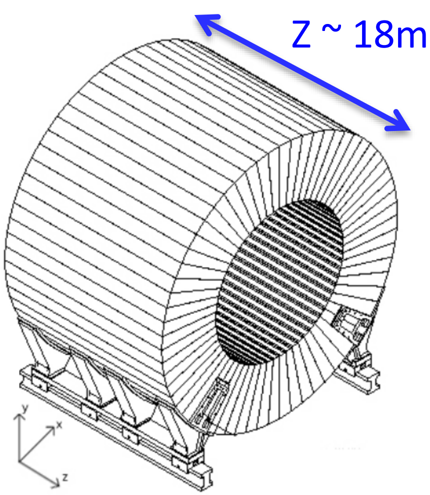
10 k channels ; ΔηxΔϕ=0.1x0.1 ; 3 longitudinal layers in LHC

Cost/performance compromise in electronics costs (~730CHF/channel in 1998)

Minimal changes needed in optics/mechanics to exploit full granularity at FCC-hh

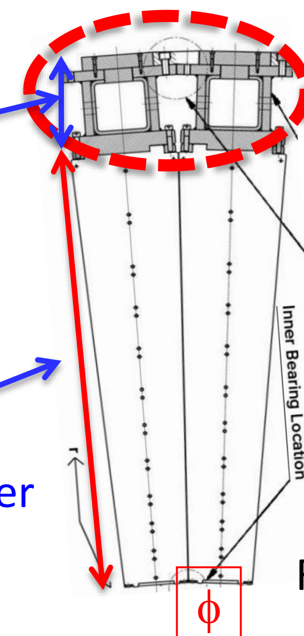
Main R&D/improvements needed in Mechanics vs ATLAS

- Stainless Steel (ok) for faster showers, less μ tails, non magnetic for solenoid compatibility
- **Increase cells thickness to at least 10λ** (assuming 2λ e.m. calo + tracker (?))
- **Redesign outer support/girder:**
  - reduce girder thickness (ATLAS ~30 cm; 1.5λ)
  - optimize electronics location/space (no need to shield Si-PMT)
  - Optimize fibres to Si-Pmts coupling (not yet studied)
- **Improve ϕ granularity to $\Delta\phi$= 0.05= 120 modules;** (64 modules;$\Delta\phi$= 0.1 in ATLAS). Could study also 180 modules and implications on girder design if needed)
- **Mechanics granularity in Z:**
  - Propose central barrel in 3 cylinders of ~ 6m each (ATLAS Tilecal barrel=5.6m)
  - Minimize cracks in the Z between 3 cylinders (not yet studied)
- Optimize supports/interface with solenoid (not yet studied)

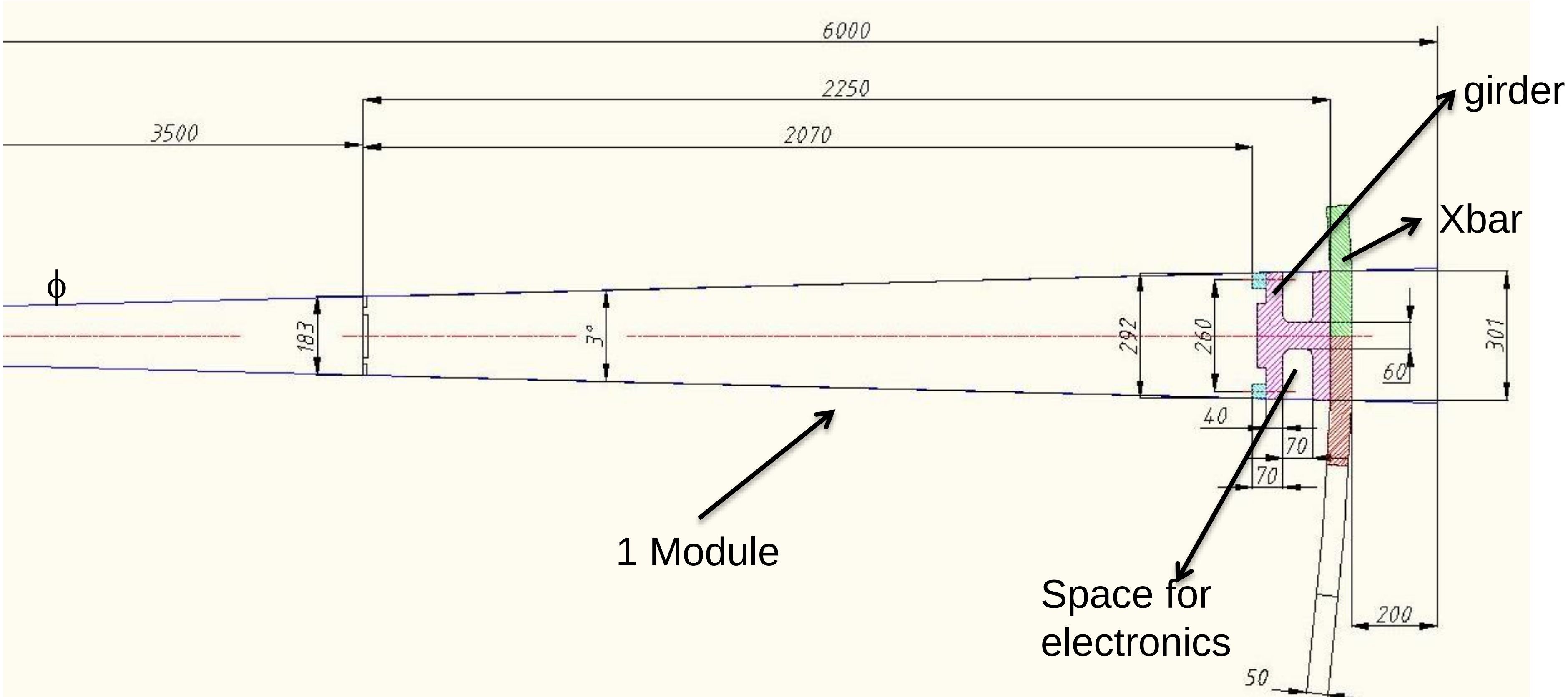


Redesign support

Increase depth,
Increase number modules in cylinder
Reduce ϕ dimensions

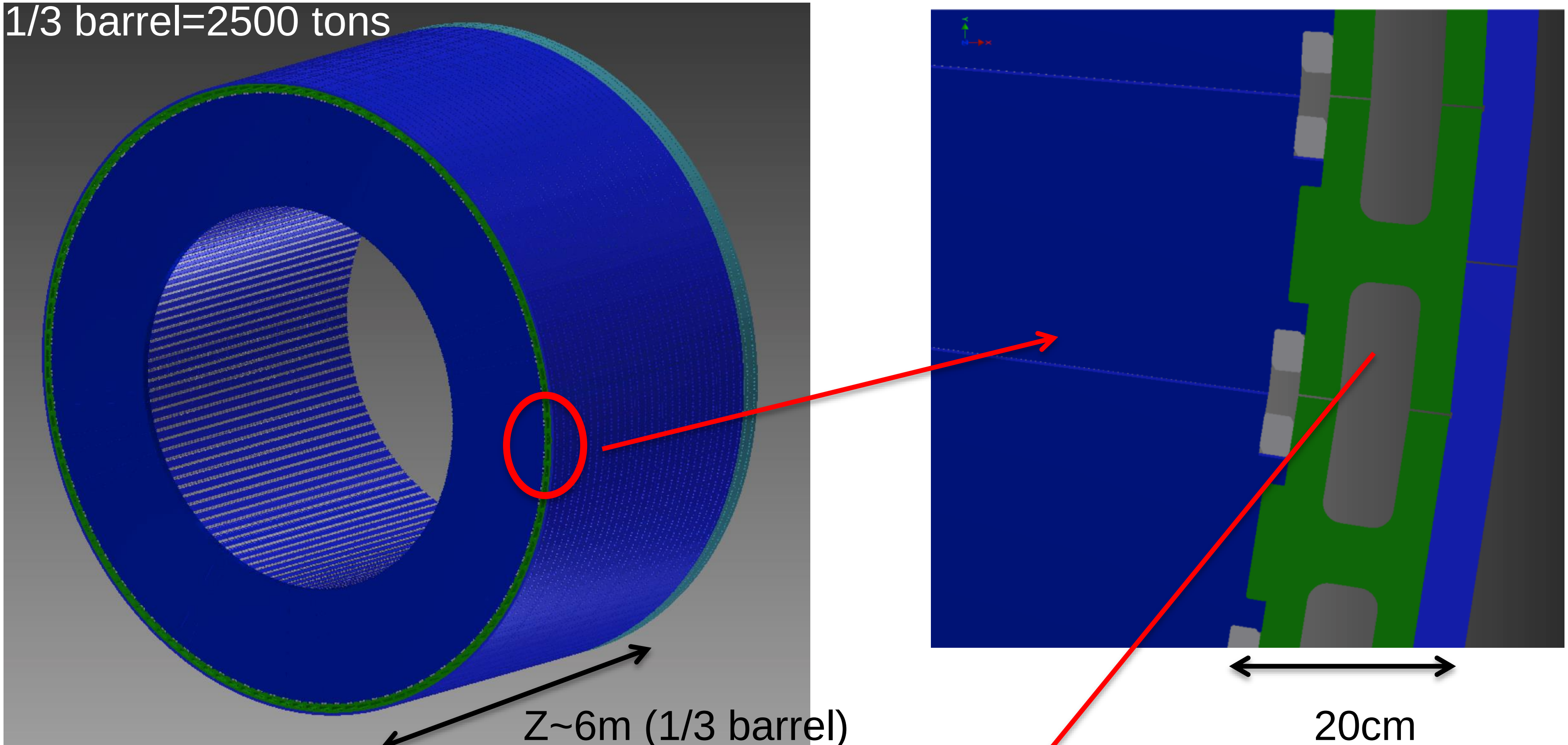


FCC Tile Had. Calo module Dimensions (version 120 modules in a cylinder)



- **120 modules in ϕ** , 6m long in Z is ok => Δϕ =0.05, 2 times better than ATLAS
- **Rmin=3.5m** (OR 3.4m IF em calo+tracker <2λ). Need to keep 12λ in total…
- **Rout =5.8m** (with supports and Xbars). Need 20cm for cables before solenoid…
- Depth active cells = 207 cm = 10λ (+29% than ATLAS; $\lambda_{tilecal}$=20.7cm).
- **Depth Outer Supports=20cm** (15cm girder+5cm Xbars);~1.5 shorter than ATLAS !
- 20 tons each module of 6 m long in Z + 0.7 tons Xbars per module
- **Total FCC Tilecal barrel weight of 18m long = 7500 tons (3x2500)**

1/3 FCC Tile Had. Calorimeter barrel (version 120 modules and 6m length)



- Barrel made of 3 cylinders of ~ 6m long each (need to minimize cracks in Z between 3 cylinders, not yet studied)
- <u>Reduced support radius/space for drawers electronics (Si-PMTS+FE electronics)</u>
- Need carefully design to access electronics in shutdowns, moveable in Z, with good alignment between fibres-Si-PMTS along 18m overall cylinder…(not yet studied)

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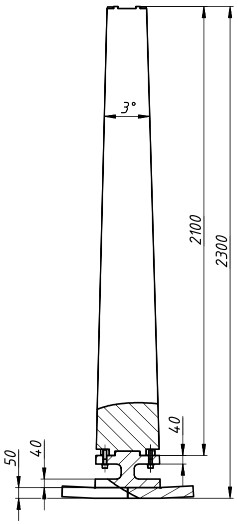

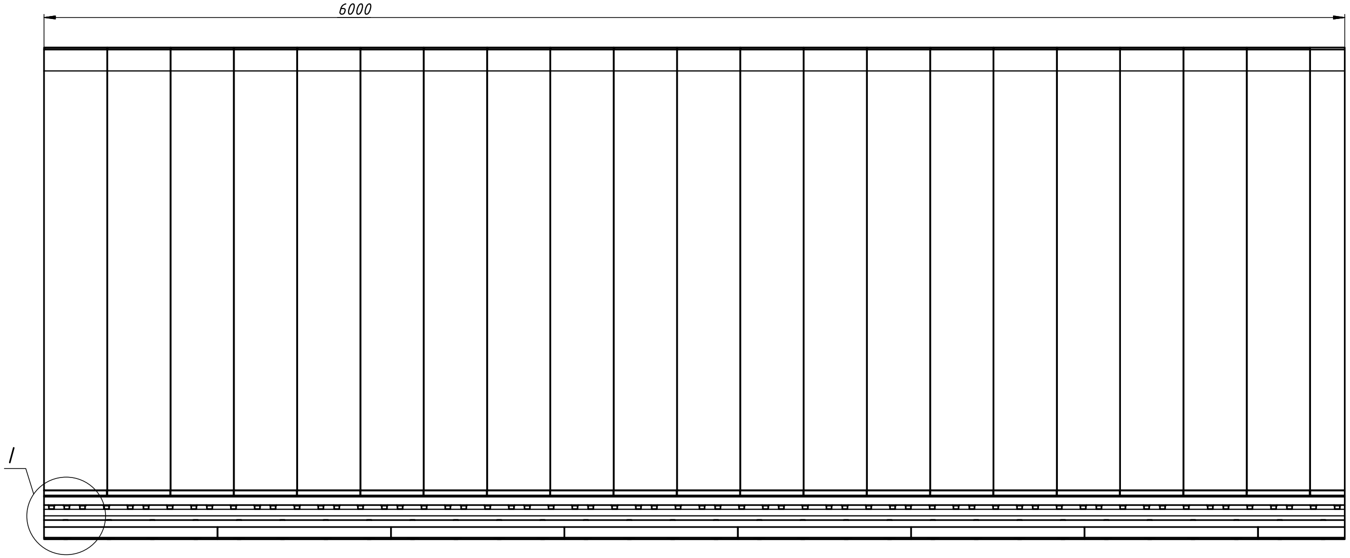

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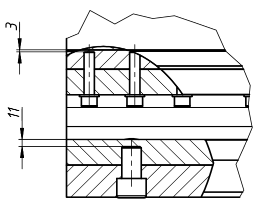

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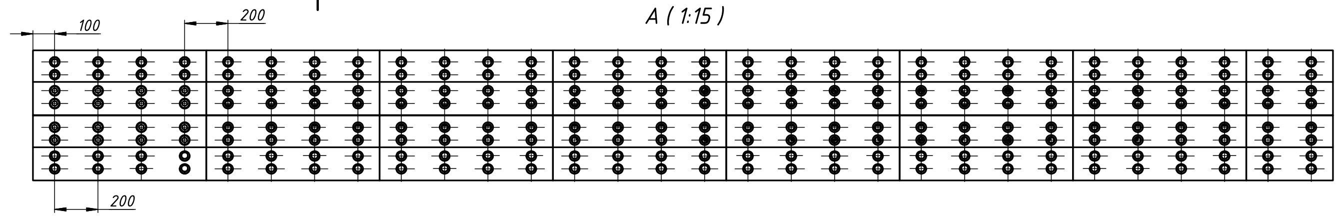

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Разраб.		Sergey		29.10.2015			25555,4	1:15
Пров.						Лист	Листов 1	
Т. контр.								
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Перв. примен.
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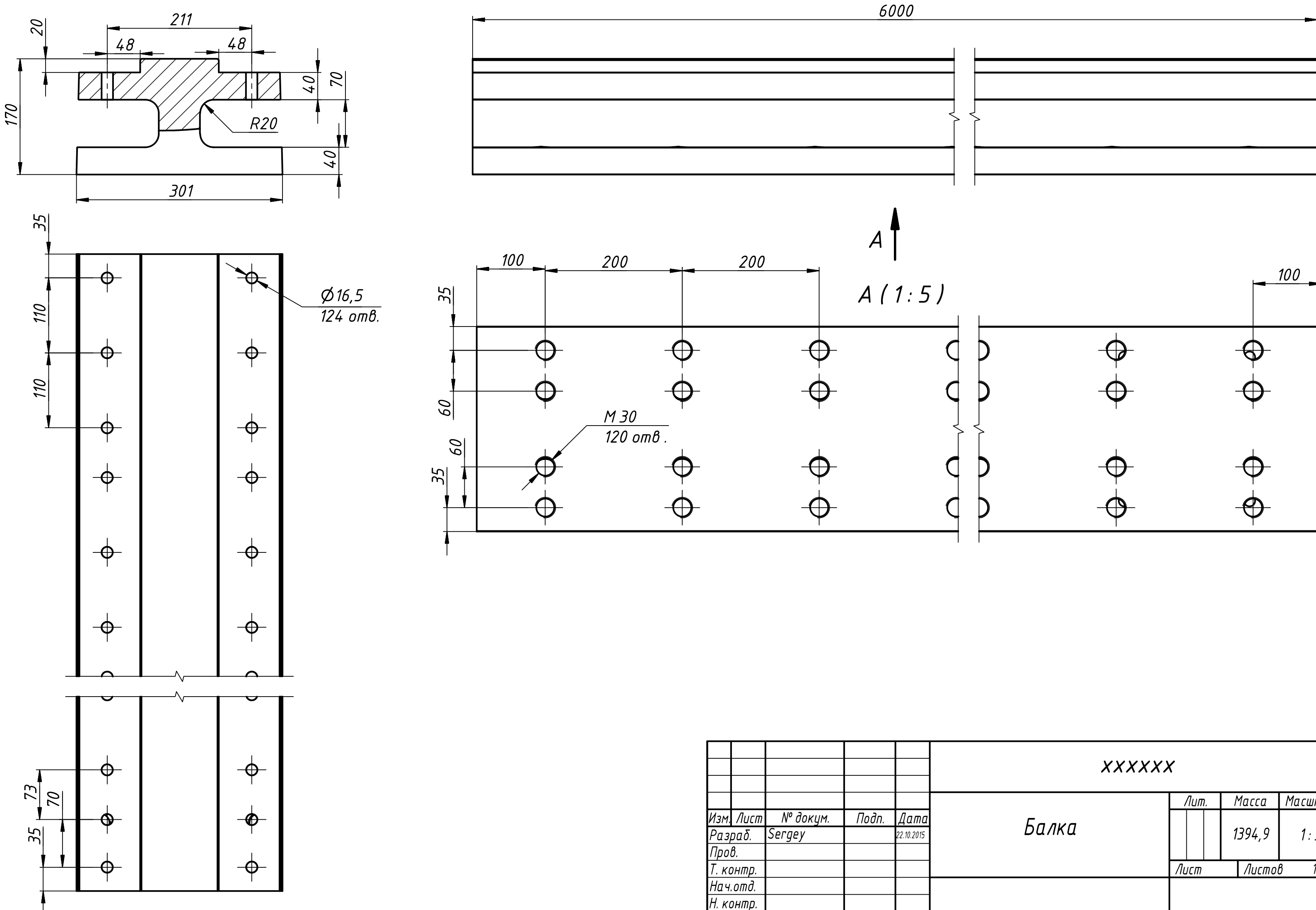

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Разраб.		Sergey		22.10.2015	
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Балка

Лит.	Масса	Масштаб
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Лист	Листов 1	

Перв. примен.

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Подп. и дата

Инв. № дубл.

Взам. инв. №

Подп. и дата

Инв. № подл.

Summary

- It is feasible ϕ granularity=0.05 (120 modules /cylinder; Rin=3.5m ; Rout = 5.8m ; Tilecal effective depth =10λ=2.07m= (assuming 2λ in em calorimeter). If $\Delta\phi$=0.025 is needed can be "easily" achieved using half trapezoidal tiles and single fibre readout.
- Outer support reduced to ~ 20cm (~1λ)
- Propose divide barrel in 3 cylinders (~6m max each in Z), but need to minimize cracks in Z…
- Need to optimize interface fibres-Si-PMTS, new location of electronics and it's access during maintenance
- Need to look at supports and interface with solenoid and em calo not studied
- etc, etc,….

Back-up slides

Main R&D/improvements needed for an "ATLAS-Tile layout using si-PMTS" in the central HCAL FCC-hh detector (η~<1.5) (cont.)

Optics:

- R&D on more radiation hard scintillators/fibres (> safety factors)
- Improve ϕ granularity. Possible cumulative actions

  Example $\Delta\phi$ =0.1-> 0.025:

  – Move outer radius; R_{min} =2.2 m (ATLAS-tilecal) -> 3.0m => $\Delta\phi$ =0.1 -> 0.07 (64 ->87 modules in cylinder).
  – Half trapezoidal tiles read by fibres in 1 side ($\Delta\phi$ =0.07-> 0.035) ; 87 modules; loose light and uniformity
  – Modules/tiles with smaller ϕ dimensions ($\Delta\phi$ =0.035 -> 0.025 (87 -> 122 modules/cylinder)
- Optimize depth granularity with the best match tiles-fibres and Tile depth dimensions (depends on real needs)
- ….

ATLAS Tile calorimeter characteristics

Characteristics	ATLAS $|\eta|<1.7$
Absorber Absorber/scintillator ratio Geometry Tiles-Fe periodicity in Z	Steel 4.7:1 Tiles & fibres ⊥ to pp beam axis 18 mm (3mm Tiles+14mm Fe)
Tiles characteristics: - Tile dimensions ($\eta x \phi x R$): - Inner radius - Outer radius - WLS Fibres	Polystyrene+1.5%PTP+0.04%POPOP by injection molding, no grooves ; ~ 70 tons 11 trapezoidal sizes in depth/R ; ~ 40105 tiles 3 mm x ~22 cm x ~10 cm ; 3 mm x ~35 cm x ~19 cm Kurary Y11 ; 1mm diameter ; ~1062 Km ; ~620 000 fibres
3 cylinders (Barrel+2 Ext B): Length in Z Outer radius(w/supports+elect.) Outer active radius Inner active radius Active depth ΔR at $\eta=0$ Volume (inner-outer active R) Weight	 12m 4.2 m 3.9 m 2.3 m 1.6m; 7.7 λ 372m3 2900 T
Longitudinal Segmentation	3 layers
Transversal granularity ($\Delta\eta x \Delta\phi$)	0.1x0.1 inner and middle layers ; 0.2x0.1 outer layer
# channels/PMTs	10 000 channels
Gain-dynamic range	10^5 ; 2 gain 10 bits ADCs
Xo ; λ_p ; Moliere Radius	22.4 mm ; 20.7 cm ; 20.5 mm

ATLAS Tile calorimeter Performance

Characteristics	ATLAS $\|\eta\|<1.7$
Light yield	70 phe/GeV
σ_E/E (tbeam standalone)	52%/√E+ 5.7% (7.7 λ) 45%/√E+2 % (if 9.2 λ)
Jet resolution target	~50-60%/VE $\oplus$ 3%
e/h	1.33
em sampling fraction	3%
Max dose at HL LHC (3000 fb-1) Max light reduction due to irradiation in run1 Max. light reduction expected at HL LHC	0.2Mard -2% -15%

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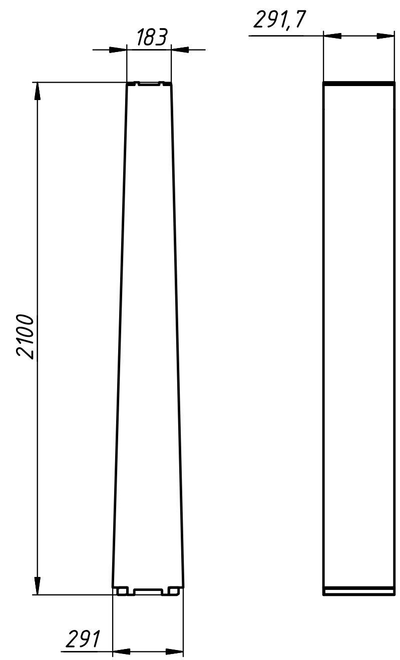

Перв. примен.

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Подп. и дата

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Подп. и дата

Инв. № подл.

Изм.	Лист	№ докум.	Подп.	Дата
Разраб.	Sergey			29.10.2015
Пров.				
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FCC Module

Лит.	Масса	Масштаб
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Лист | Листов 1

Копировал

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