ATLAS IBL Overview

LHCC Upgrades session

CERN, September, 21^{2t} 2010

G. Darbo - INFN / Genova

Indico agenda page:

- *http://indico.cern.ch/conferenceDisplay.py?confId=107477*

Outline

- *Timeline and History of the IBL project*

- *Motivation for IBL*
  - Ensure excellent tracking, vertexing and b-tagging performance during LHC phase I
  - Recover from eventual failures in present Pixel system, especially in the present B-layer
  - Add to robustness of tracking with high luminosity pileup

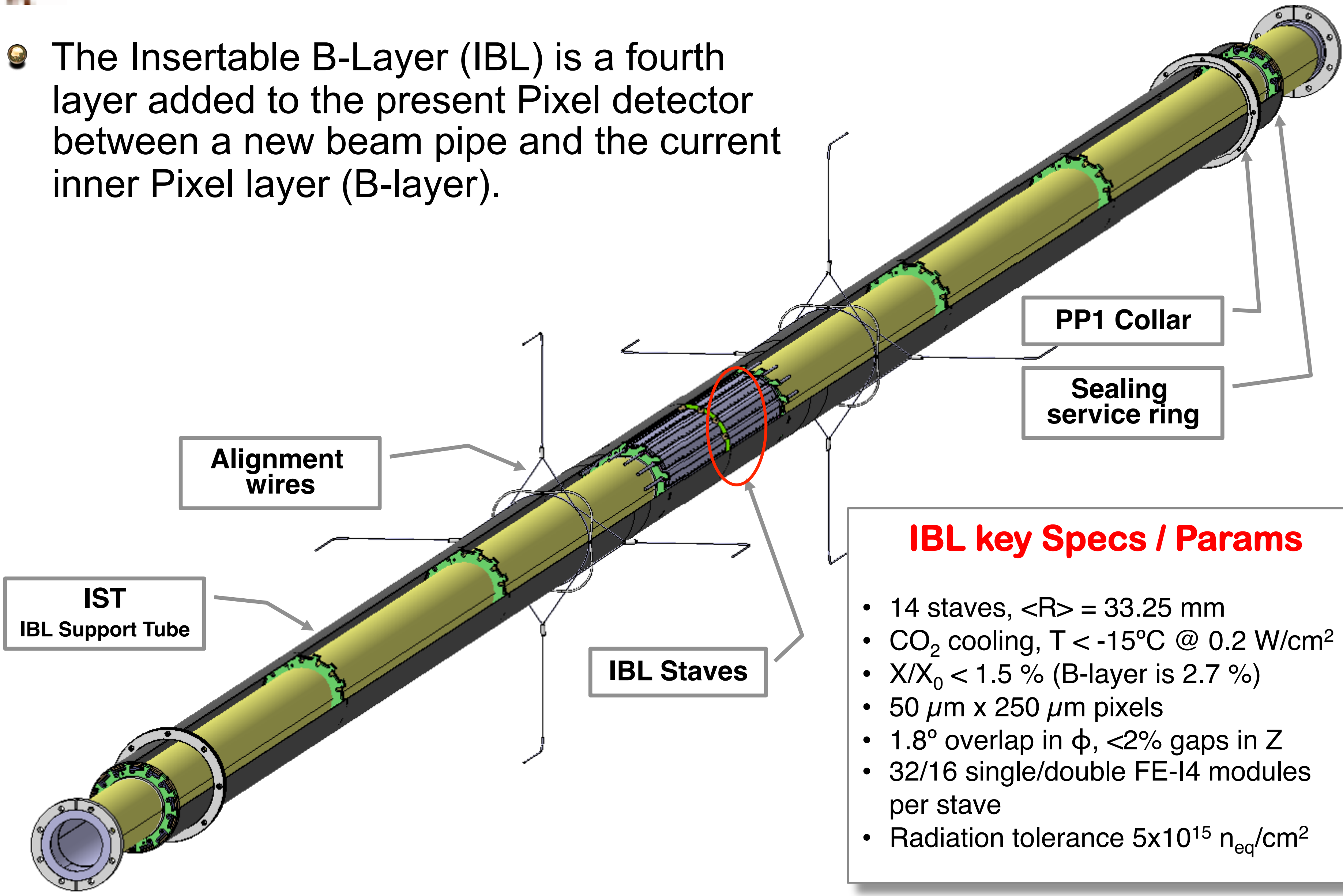
- *Status and Organization*
  - Plan to be ready in 2015
  - Sensor choice in 2011
  - ATLAS project, Organization in place, TDR, interim-MoU, expected cost

- *Study of tracking, vertexing and b-tagging performance:*
  - Markus's talk

- *IBL Technical Description and status*
  - Heinz's talk

IBL Detector

- The Insertable B-Layer (IBL) is a fourth layer added to the present Pixel detector between a new beam pipe and the current inner Pixel layer (B-layer).



IBL key Specs / Params

- 14 staves, <R> = 33.25 mm
- CO_2 cooling, T < -15°C @ 0.2 W/cm^2
- X/X_0 < 1.5 % (B-layer is 2.7 %)
- 50 μm x 250 μm pixels
- 1.8° overlap in ϕ, <2% gaps in Z
- 32/16 single/double FE-I4 modules per stave
- Radiation tolerance 5×10^{15} n_{eq}/cm^2

History of IBL Project - Time Line

- *1998: Pixel TDR*
  - B-layer designed to be substituted every 3 years of nominal LHC (300 fb^{-1}): due to then available radiation hard sensor and electronic technologies.
- *2002: B-layer replacement*
  - became part of ATLAS planning and was put into the M&O budget to RRB.
- *2008: B-layer taskforce*
  - B-layer replacement cannot be done – Engineering changes to fulfil delayed on-detector electronics (FE-I3, MCC) made it impossible even in a long shut down.
  - Best (only viable) solution: "make a new smaller radius B-layer insertion using technology being developed for HL-LHC prototypes". This became the IBL.
- *2009: ATLAS started IBL project:*
  - February: endorsed IBL PL and TC
  - April: IBL organization in place (Endorsed by the ATLAS EB)
- *2010: TDR and interim-MoU*
  - TDR is under approval in ATLAS
  - Interim-MoU is collecting last signatures.

Status and Failure Analysis in Current Pixel Detector

- Irreparable failures of modules in the B-layer, and in other Pixel layers, will appear with time: today 2.41 % of B-layer / 3.01 % of the whole pixel is dead.

Failures and IBL adopted solutions:

- Experience gained from failures in present Pixels leads to improved design for IBL.
  - **Titanium pipes:** corrosion resistant.
  - **Permanent pipe joints inside the detector:** avoid leakage at fittings.
  - **Move opto-boards to ID endplate:** more easily serviceable site.

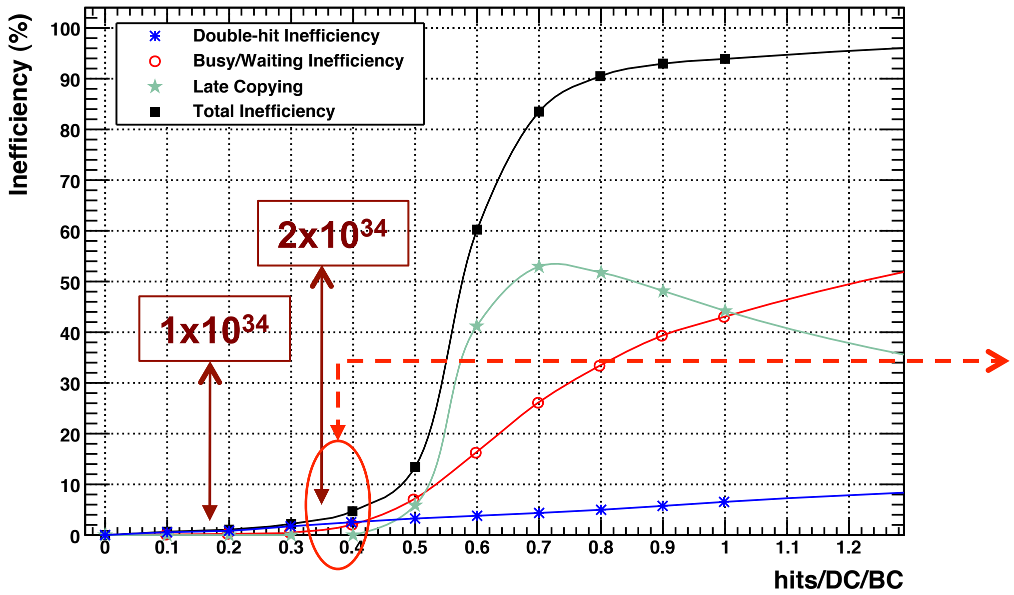
Affected System (failure classes)	No. of parts in the system	No of part fail / % of dead pixels	
		Whole Pixel	B-layer only
Pixel	80 363 520	161 k / 0.20 %	15 k / 0.11 %
Front-end	27 904	42 / 0.15 %	9 / 0.20 %
Module	1 744	40 / 2.29 %	6 / 2.10 %
Opto-board	272	1 / 0.37 %	- / 0.00 %
Cooling loop (high leak)	88	(3) / 0.00 %	(0) / 0.00 %
Total dead pixels		**3.01 %**	**2.41 %**

Occupancy Induced Inefficiencies in Present B-layer

Luminosity effects:

- The current Pixel detector (FE-I3, MCC) designed for a peak luminosity of 1×10^{34} $cm^{-2}s^{-1}$.
- A luminosity at least twice that high is expected before the High Luminosity LHC (HL-LHC) is complete after 2020. (S.Myers at ICHEP: 2.2×10^{34})
- Event pileup: requires redundancy in the measurement of tracks to control the fake rate
- High occupancy: can induce readout inefficiencies, affects the B-layer more than other layers and would thereby limit the *b* tagging efficiency.
- **IBL**: low occupancy (with respect to SCT/TRT) reduces track fakes, FE-I4 has higher bandwidth than existing readout.

FE-I3 inefficiency vs occupancy for B-layer



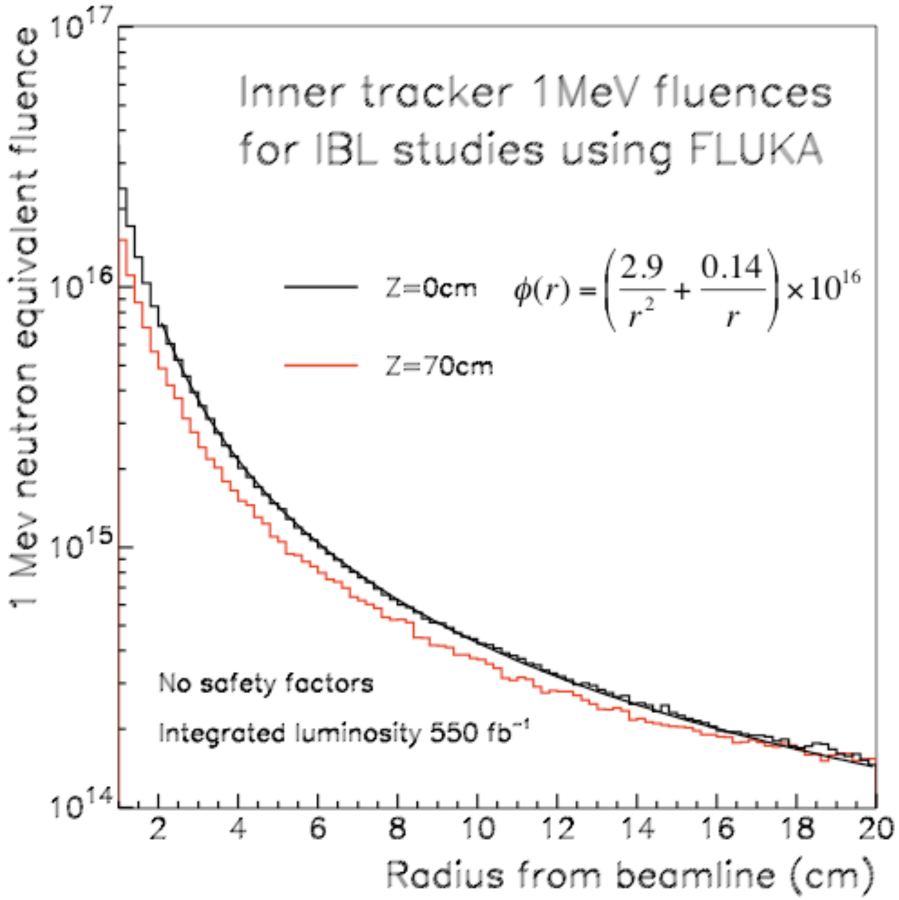
FE-I3 has 5% inefficiencies at the B-layer occupancy for 2.2×10^{34}. Steep rising function of occupancy: no safety margin.

Radiation and Operation of IBL

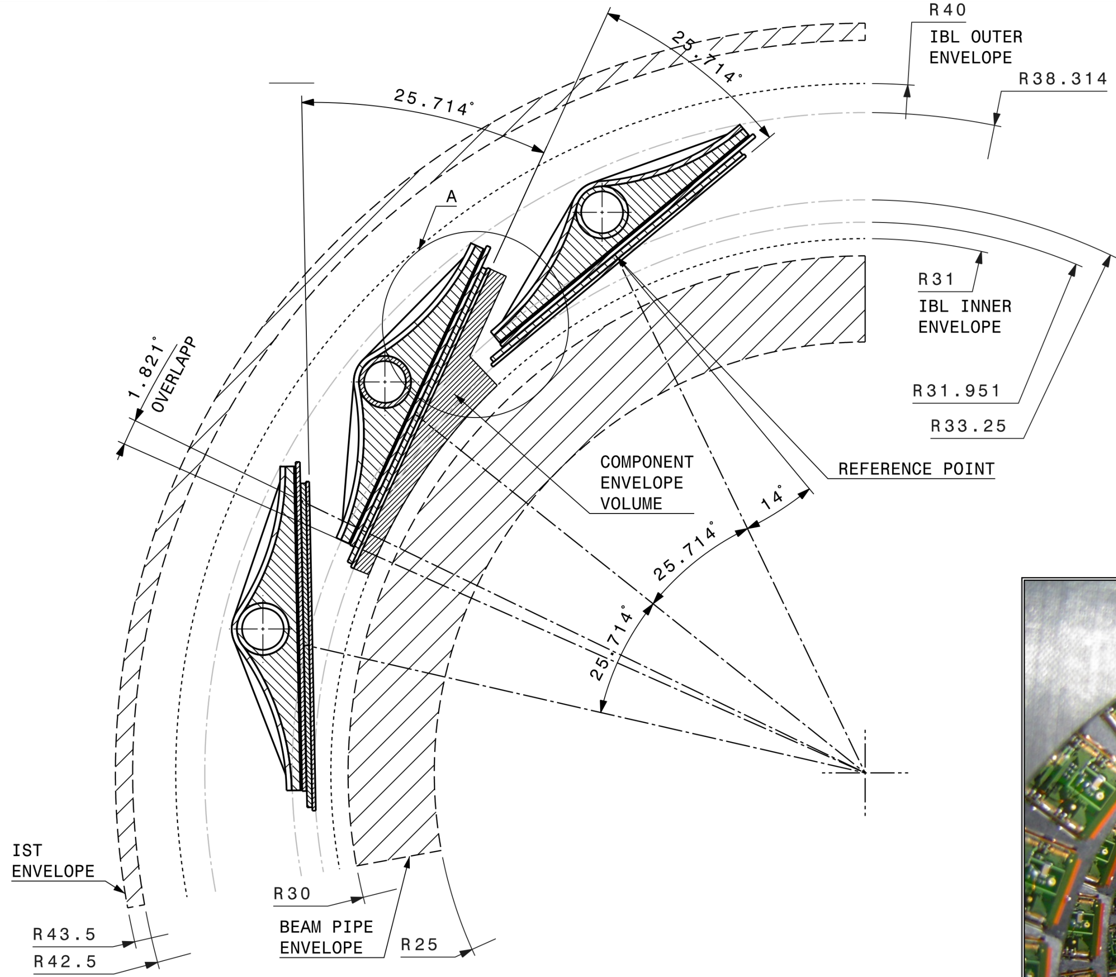
- ***Large radiation doses:***
  - With current expectations of the LHC luminosity profile (S.Myers at ICHEP 340 fb^{-1} in 2020), radiation life dose is less of an issue than it was at the time of the Pixel TDR (730 fb^{-1} in the Pixel life).

IBL: designed for 550 fb^{-1} (provides margin should luminosity evolve more rapidly than expected or should 2020 HL-LHC shutdown be delayed)

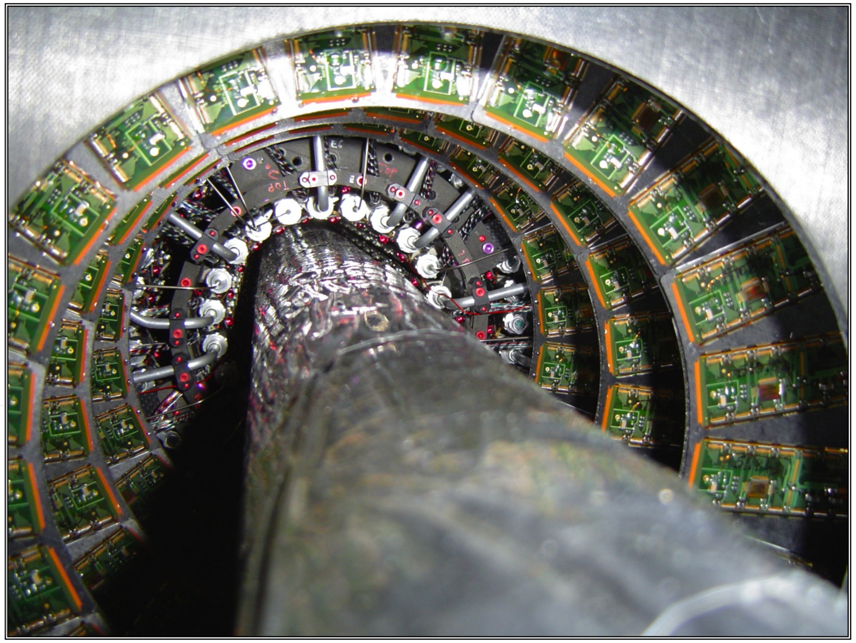
- At R = 3.2 cm corresponds to 3.3 × 10^{15} n_{eq}/cm^2
- Life dose requirements (with safety factors):
  - NIEL: 5.0 × 10^{15} n_{eq}/cm^2
  - TID: 250 Mrad



IBL Layout



- *Beam-pipe reduction:*
  - Inner R: 29 → 25 mm
- *Very tight clearance:*
  - "Hermetic" to straight tracks in Φ (1.8º overlap)
  - No overlap in Z: minimize gap between sensor active area.
  - Coverage in η (2σ-vertex spread): 2.6
- *Material budget:*
  - Stave, el.serv. Module: 1.16 % X_0
  - IBL Sup.Tube (IST): 0.28 % X_0



- *Beam-pipe (BP) extracted by cutting the flange on one side and sliding (guiding tube inside).*
- *IBL Support Tube (IST) inserted.*
- *IBL with smaller BP inserted in the IST*

Schedule Plan

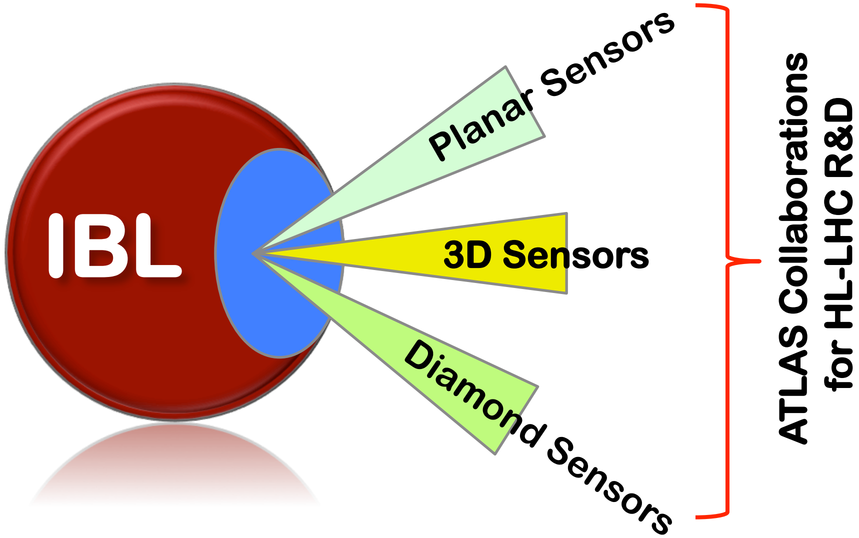
- *The IBL schedule is a compromise between:*
  - the drive to have the IBL ready as soon as possible, in order to benefit from its potential to recover possible irreparable failures of the existing B-layer (and of the Pixel detector more generally),
  - and the time demanded for the substantial technology developments (to fit and perform to IBL requirements) and qualification tests required.

- *The IBL is scheduled "ready for installation" in May 2015 in case of an unexpectedly large failure rate of the current Pixel detector.*
  - In the absence of such problems, it will be installed in the long LHC shutdown foreseen for 2016.
  - $\geq$ 8 months shutdown needed for opening ATLAS, removing the beam-pipe and install the IBL + smaller beam-pipe.

- *The IBL is in the roadmap of the new Pixel detector at HL-LHC:*
  - In addition to serving ATLAS until the HL-LHC upgrade in 2020, the IBL project will develop technologies and valuable experience for the subsequent high luminosity era.

Module Prototype Program

- *Three candidate sensor technologies address the IBL requirements with different trade-offs:*
  - Planar sensor n-on-n and n-on-p, 3D sensors with active edge (or <200μ edge), pCVD Diamond sensor
- *The module format satisfied with any of these technologies, thus some independence. Two parameters: operating temperature and bias voltage are different.*
  - Planar sensors require the lowest temperature and high bias voltage, but have very well understood manufacturing sources, mechanical properties, relatively low cost, and high yield.
  - 3-D sensors require the lowest bias voltage, intermediate operating temperature, and achieve the highest acceptance due to active edges, but their manufacturability with high yield and good uniformity must be demonstrated.
  - Diamond sensors require the least cooling and have similar bias voltage requirements to planar sensors, but their manufacturability with high yield, moderate cost, and good uniformity must all be demonstrated.

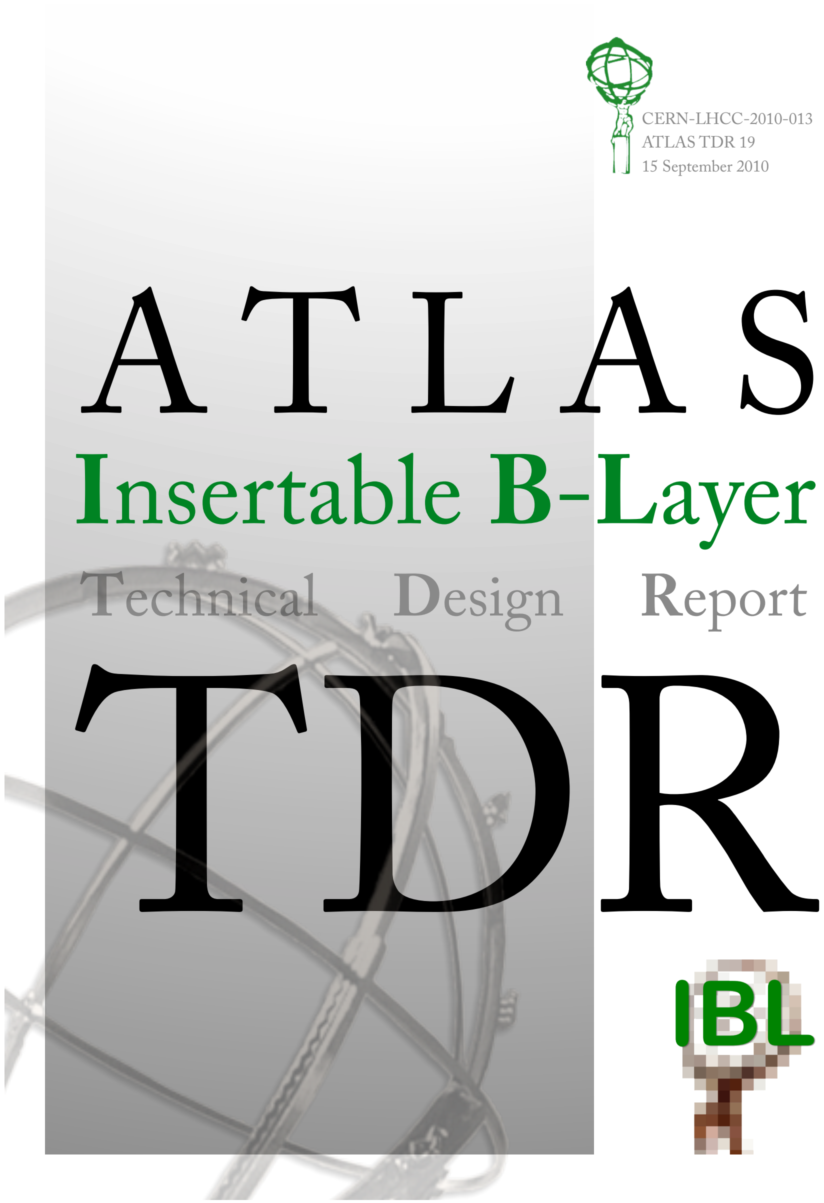


Selection in summer 2011 driven by:

- Module performance after irradiation and with test beam measurements.
- Understanding of manufacturing yield

IBL Technical Design Report

- *ATLAS TDR includes:*
  - Overview and motivation for the project
  - Study of the physics performance
  - Technical description of the project with baseline and options for critical issues
  - Three sensor technologies.
  - Beam-pipe, extraction/insertion, installation, ALARA.
  - Organization of the project and resources



- *Editorial team:*

M. Capeans (technical editor), G. Darbo, K. Einsweiller, M. Elsing, T. Flick, M. Garcia-Sciveres, C. Gemme, H. Pernegger, O. Rohne and R. Vuillermet.

CERN-LHCC-2010-13, ATLAS TDR 19

Memorandum of Understanding

- *Decided to go to an interim-MoU (iMoU):*
  - Until decision on sensor technology (Summer 2011)
  - Consolidate interest of Institutes and availability of funds
  - Status: Funding Agencies involved are sending their signed copies. The dead-line was end of August and we are waiting for the last ones to send them in.

- *Annexes:*
  - Define cost accordingly to project WBS (9.7 MCH)
  - Participating Institutes/Institutions
  - Sharing of work and cost amongst institutes.

List of IBL Sub-units

	System	MoU Item	Description	Cost (kCH)
1	**Module**	1	Sensor - prototype (including bumping to FE-I4), production, procurement & QC	752
		2	FE-I4 prototype (v1), production (v2), test	1 372
		3	Bump-bonding, thinning, bare module - prototype, production & QC	726
2	**Stave**	4	Local support (stave): CF structure, TM, pipe - prototype, production & QC	467
		5	Module assembly, stave loading, flex-hybrid, internal electrical services - design, production & QC	436
3	**Off-detector**	6	R/O chain: opto-board, opto-fiber, TX/RX, BOC, ROD, TDAQ (S-link, TIM, SBC, ROS, crate)	1 025
		7	Power chain: HV/LV PS, PP2 regulators, type2, 3 & 4 cables, interlock, DCS	505
4	**Integration & Cooling plant**	8	Integration in SR1 & System test	492
		9	Cooling plant & cooling services to PP1	461
5	**Beam-pipe & Installation**	10	Beampipe & mechancal interfaces (to staves, to type 1 services, IST)	1 990
		11	Installation in the pit: beampipe extraction, IBL+beampipe insertion, services installation	1 515
			Total	**9 741**

Interim-MoU - Institutions

- *There are 43 institutions in the IBL project*
  - Large interest for the sensor (22 Institutions)
  - Full effort and funding requirements are covered
- *300 people have expressed their interest to contribute to the project*
  - many have already started to work.
  - In most cases institutes contribute with money where also there is contribution with manpower.

Institutions in the IBL Construction

Institution	Country	1 Sensor	2 FE-I4	3 Bump-bonding	4 Stave	5 Mod.Load	6 R/O Chain	7 PS Chain	8 Integration	9 Cooling plant	10 BP & Interfaces	11 Installation
		IBL MoU Deliverables										
Annecy LAPP	France				1							
Barcelona	Spain	1		1				3	2			
Bergen	Norway	1										
Berkeley LBNL	United States of America		1				1				1	
Berlin HU	Germany											
Bologna	Italy						1					
Bonn	Germany	1	1	1		1			2			
Brandeis	United States of America										1	
CERN	Switzerland	1		1	1	1			1	2		
DESY	Germany						1	1				
Dortmund	Germany	1										
Geneva	Switzerland		1			1			1		1	
Genova	Italy		1			1	3	3				
Glasgow	United Kingdom	1										
Göttingen	Germany		2				1		2			
Grenoble LPSC	France										1	1
Heidelberg ZITI	Germany											
Iowa	United States of America							1	2			
KEK	Japan	1		1								
Liverpool	United Kingdom	1										
Ljubljana	Slovenia	1										
LPNHE Paris	France	1			2							
Manchester	United Kingdom	1										
Marseille CPPM	France		1		1	1						
Milano	Italy			1	1			1				
Munich MPI	Germany	2										
New Mexico	United States of America	1										
Nikhef	Netherlands		1		2					2		
Ohio State University	United States of America	1					1					
Oklahoma	United States of America						1		2			
Oklahoma SU	United States of America						1					
Orsay LAL	France	1										
Oslo	Norway	1				2			2			
Prague AS	Czech Republic	1										
Santa Cruz UC	United States of America	1				1			2			
Siegen	Germany						1					
SLAC	United States of America	1			2	1	2		2	2		
Stony Brook	United States of America	1					2		2			
Taipei AS	Taiwan						1					
Toronto	Canada	1										
Udine	Italy	1										
Wuppertal	Germany				1		1	1	2			
ATLAS TC	World Wide									1	1	1

Legend:

1	Funds/Deliverables and Personnel
2	Personnel only
3	In kind M&O-A

Conclusions

- *IBL Project going ahead well:*
  - IBL restores performance lost by failures or inefficiencies of the present tracker and improves significantly ATLAS performance with (and without) pile-up → see Markus' next talk.
  - Technical solutions and prototypes exist for all aspects of the project → see Heinz's next talks.
  - Ready to install by mid 2015.
- *Technical Design report in final approval by ATLAS.*
- *Interim-Memorandum of Understanding (iMoU) collecting last signatures.*
- *Motivated groups and Institutes provide necessary effort and funding.*
- *HL-LHC will profit of many developments from IBL.*

BACKUP SLIDES

Management Board (MB)

MB ad-interim membership

IBL Project Leader: G. Darbo
IBL Technical Coordinator: H. Pernegger
"Module" WG (2 Physicists): F. Hügging & M. Garcia-Sciveres
"Stave" WG (1 Phy. + 1 M.E.): O. Rohne + D. Giugni
"IBL Assembly & Installation" WG (2 M.E. initially, a Phy. Later): F. Cadoux + R. Vuillermet
"Off-detector" WG (1 Phy. + 1 E.E.): T. Flick + S. Débieux

"Extra" members:

IBL/Pixel "liaison": Off-line SW: A. Andreazza, DAQ: P. Morettini, DCS: S. Kersten
Ex officio: Upgrade Coordinator (N. Hessey), PO Chair (M. Nessi), Pixel PL (B. Di Girolamo), ID PL (P. Wells), IB Chair (C. Gößling)

IBL Management Board (MB)

Membership:
- IBL PL + IBL TC
- 2 cordinators from each WG
- Plus "extra" members

Module WG (2 cordinators)

- FE-I4
- Sensors
- Bump-Bonding
- Modules
- Procurement & QC
- Irradiation & Test Beam

Stave WG (1 Phys + 1 Eng.)

- Staves
- Cooling Design & Stave TM
- HDI (Flex Hybrid)
- Internal services
- Loaded stave
- Procurement & QC

Integration & Installation WG (2 Eng.)

- Stave Integration
- Global Supports
- BP procurement
- Ext. services inst.
- BP extraction
- IBL+BP Installation
- Cooling Plant

Off-detector (1 Phys + 1 E.Eng.)

- BOC/ROD
- Power chain & PP2
- DCS & interlocks
- Opto-link
- Ext. serv .design/proc.
- Procurement & QC
- System Test