Update on ATLAS insertable B-layer

LHCC Upgrade session

CERN, September, 22nd 2009

G. Darbo - INFN / Genova

Indico agenda page:

- *http://indico.cern.ch/conferenceDisplay.py?confId=67640*

IBL Project Status

- *Project approved by ATLAS*
  - Project Leader endorsed by ATLAS CB (February 20th)
  - IBL has put in place its management structure (Management Board) – Endorsed by ATLAS EB (April 3rd)
- *ATLAS Institutes Participation*
  - IBL Kick-off (July 8th) meeting with Institute's Leaders to focus participation in the project.
  - Large interest in the project (~35÷40 institutes participated at the kick-off meeting and have shown interest in parts of the project)
  - Project cost evaluated and funding model proposed: 4.0 MCH (M&O-A), 5.6 MCH (M&O-B, new project)
- *Technical Design Report (TDR)*
  - Main editor / technical editor (K. Einsweiler / M. Capeans) and chapter editors in charge
  - Few editor's meetings since end of July, TDR foreseen for April 2010.
- *Memorandum of Understanding foreseen in "interim" form by the end of the year:*
  - MoU will be signed after TDR (spring 2010)

IBL Organisation Structure

Whole project divided into 4 working groups

- IBL Management Board has 10 members, plus "extra" and ex-officio members.
- Frequent meetings (every ~14 days) in this phase of the project.

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): N. Hartman + R. Vuillermet
"Off-detector" WG (1 Phy. + 1 E.E.): T. Flick + S. Débieux

"Extra" members:

Ex officio: Upgrade Coordinator (N. Hessey), PO Chair (M. Nessi), Pixel PL (B. Di Girolamo), ID PL (P. Wells), Pixel Chair (C. Gößling)
Offline "liaison" Pixel Off-line coordinator: A. Andreazza
TDR editor (temporary): K. Einsweiler

IBL Management Board

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

Module WG (2 coordinators)
- **FE-I4**
- **Sensors**
- **Bump-Bonding**
- **Modules**
- **Test & QC**
- **Irradiation**

Stave WG (1 Phys + 1 Eng.)
- **Staves**
- **Cooling Design & Stave Thermal Management**
- **HDI**
- **Internal Services**
- **Loaded Stave**
- **Test & QC**

IBL Integr.-Install. (2 Eng.)
- **Stave Integration**
- **Global Sup.**
- **Beam Pipe (BP)**
- **Ext.services inst.**
- **IBL+BP Installation**
- **Cooling Plant**
- **Test & QC**

Off-detector (1 Phys + 1 E.Eng.)
- **Power**
- **DCS**
- **ROD**
- **Opto-link**
- **Ext.serv.design/proc.**
- **Test Beam**
- **System Test**

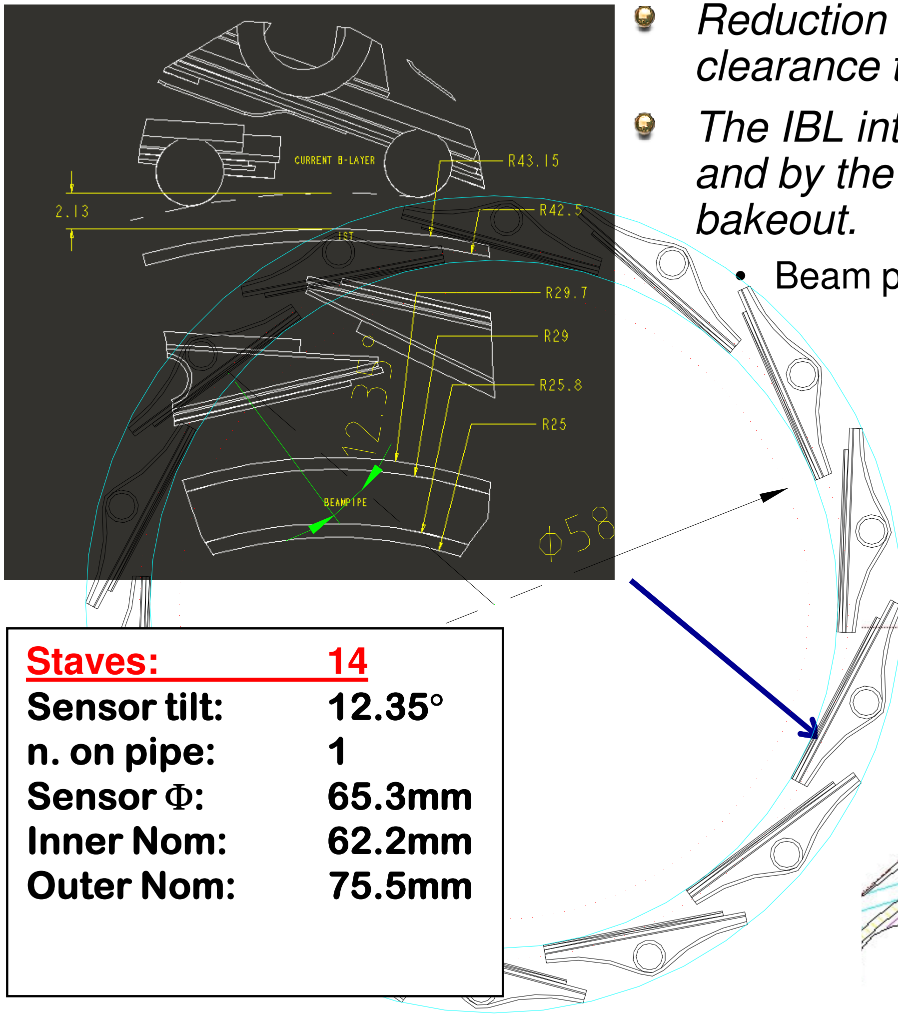
TDR - Schedule

Action		Deadline	# Weeks from previous
TDR	Printout, submission to LHCC	April 1st 2010	2
Final Draft	Deadline for comments	March 15th 2010	2
	Sent to Collaboration for Approval	March 1st 2010	2
Draft 2	Deadline for comments	Feb 15th 2010	3
	Sent to Collaboration	Jan 25th 2010	2
Draft 1	Deadline for comments	Jan 11th 2010	4
	Sent to Collaboration	Dec 15th 2009	2
	Approval by TDR Editors and PO/USG	Dec 1st 2009	2
Preparation	TDR Integration	Nov 16th 2009	3
	Editors meeting 4 - final internal draft	October 19th 2009	3
	Editors meeting 3	September 28th 2009	3
	Editors meeting 2	September 7th 2009	3
	Editors meeting - final chapter's structure	August 19th 2009	3
	Editors Kick off meeting	July 22nd 2009	

IBL Layout and New Beam Pipe

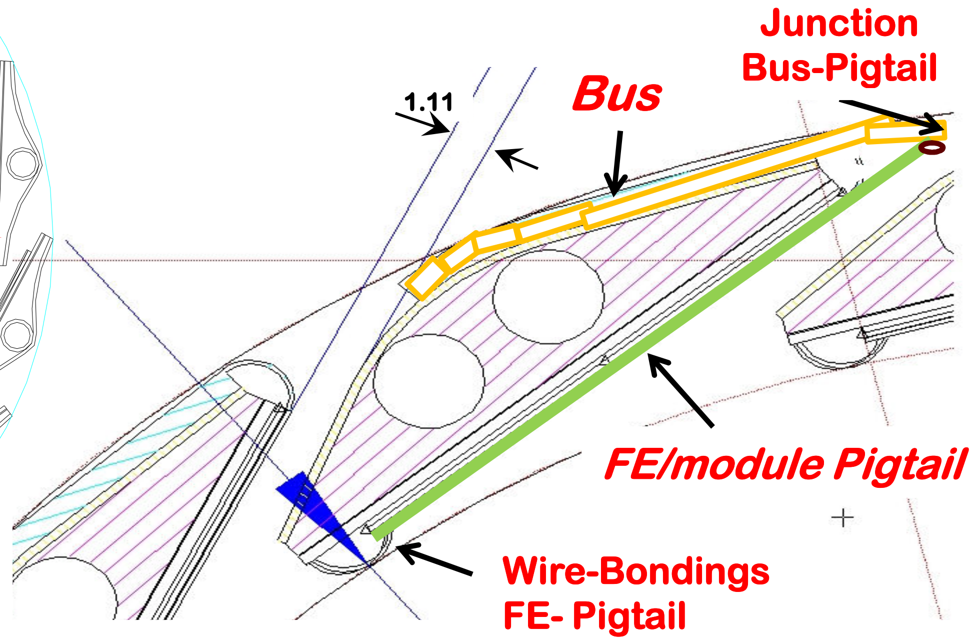
- Several layouts under study: 14 staves at R_{min}=~3.1 cm
  - *Single and double staves – One or two (redundant) cooling channels*

- *Reduction of beam-pipe (ID from 29R to 25R) allows enough clearance to fit the IBL*
- *The IBL internal envelope is defined by the new beam pipe and by the thickness of the insulation required during the bakeout.*
  - Beam pipe ID= 50, thickness = 0.8 mm, Insulation =4 mm



Staves:	**14**
Sensor tilt:	**12.35°**
n. on pipe:	**1**
Sensor Φ:	**65.3mm**
Inner Nom:	**62.2mm**
Outer Nom:	**75.5mm**

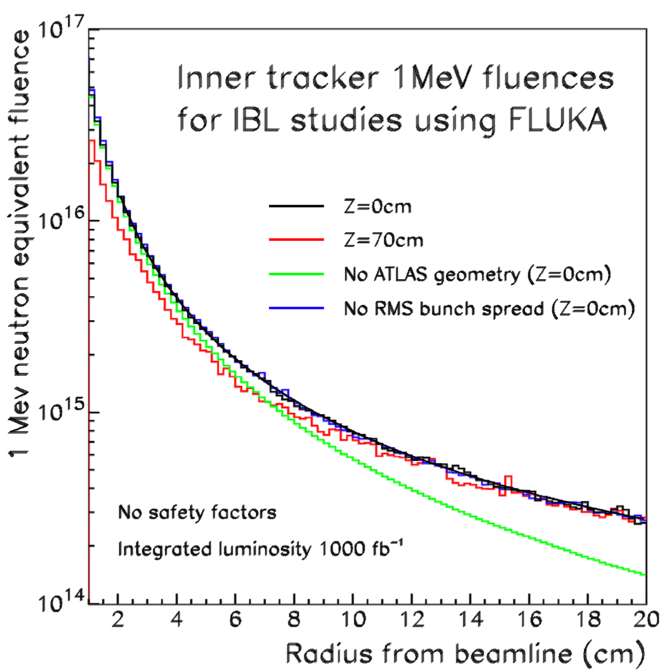
Inverted turbine



Credits: N. Hartman et al.

Requirements for Sensors/Electronics

- *Requirements for IBL*
  - IBL design Peak Luminosity = 3x10^{34} $cm^{-2}s^{-1}$ → New FE-I4, higher hit rate
  - Integrated Luminosity seen by IBL = 550 fb^{-1}
  - Total NIEL dose = 2.4 x 10^{15} ± 30% (σ_{pp}) ± 50% (damage factor) = 4.7 x 10^{15} n_{eq}/cm^2 → more rad-hard sensors
  - Total radiation dose > 200 Mrad
- *ATLAS Pixel Sensor/FE-I3 designed for 10^{15} n_{eq}/cm^2 / 50 Mrad*



- Fit made for 2 < r < 20 cm for L=1000fb^{-1}

$$\Phi(r) = \left(\frac{493}{r^2} + \frac{25}{r} \right) \times 10^{14}$$

- Gives for IBL @ 3.7 cm (550 fb^{-1}):

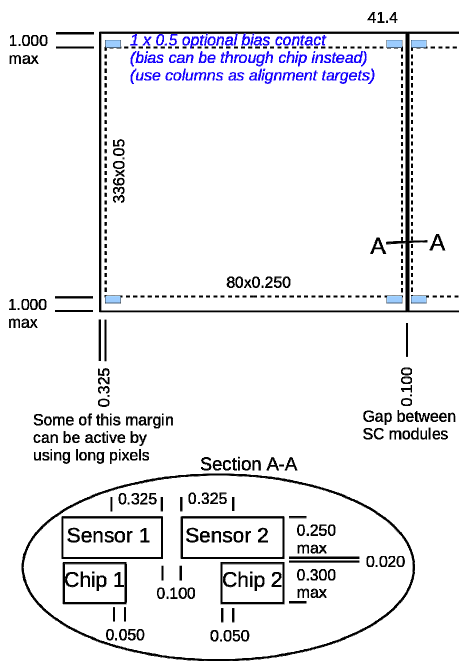
  $\sqrt{}_{1MeV}$=2.4x10^{15} (1.2 MGy)

- Safety factors not included in the computation (pp event generator: 30%, damage factor for 1 MeV fluences: 50%)

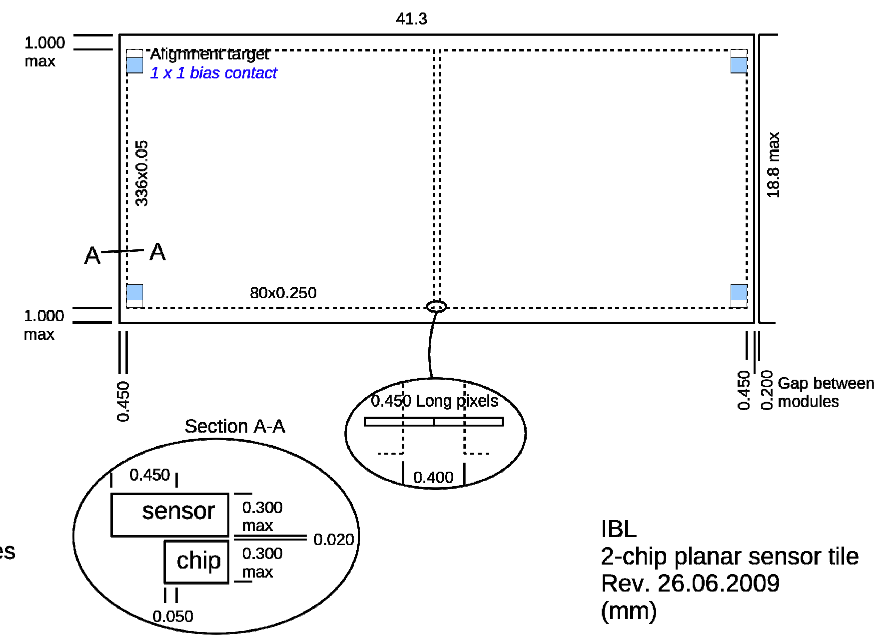
Ref. Ian Dawson – ATLAS Upgrade Week (Feb.09)

Module Layout - Convergence

- *Sensor technology (3D, Planar, Diamond) taken after TDR*
  - module prototypes with FE-I4 (second half 2010) –
  - Common Engineering specifications (layout, Max Vbias, Ibias, power) under definition to progress on cooling/stave/service design;
- *Common sensor baseline for engineering and system purposes*
  - 3D/Diamond – single chip modules / Planar sensors – 2 chip modules
- *Sensor/module prototypes for ~10% of the detector in 2010*
  - Stave prototype tested with modules and cooling



IBL
Envelope for 2 single-chip 3-D modules
Rev. 26.06.2009
(mm)



IBL
2-chip planar sensor tile
Rev. 26.06.2009
(mm)

Credits: M.Garcia-Sciveres – F. Hügging

Sensor: 3D, Planar, Diamond

- *IBL sensor developments coming from ATLAS R&D efforts – IBL define specification and requirements for the sensors:*
  - ATLAS 3D Sensor Collaboration (16 Institutes and 4 processing facilities):

    Bergen, Bonn, CERN, Cosenza, Freiburg, Genova, Glasgow, Hawaii, LBNL, Manchester, New Mexico, Oslo, Prague, SLAC, Stony Brook, Udine - Processing Facilities: CNM Barcelona, FBK-IRST (Trento), SINTEF/Stanford
  - ATLAS Planar Pixel Sensor R&D Collaboration (16 Institutes)

    Bonn, Berlin, DESY, Dortmund, MPP & HLL Munich, Udine, KEK, CNM Barcelona, Liverpool, LBNL, LPNHE, New Mexico, Orsay, Prague, Santa Cruz.
  - ATLAS Diamond R&D Collaboration (6 Institutes, 2 vendors):

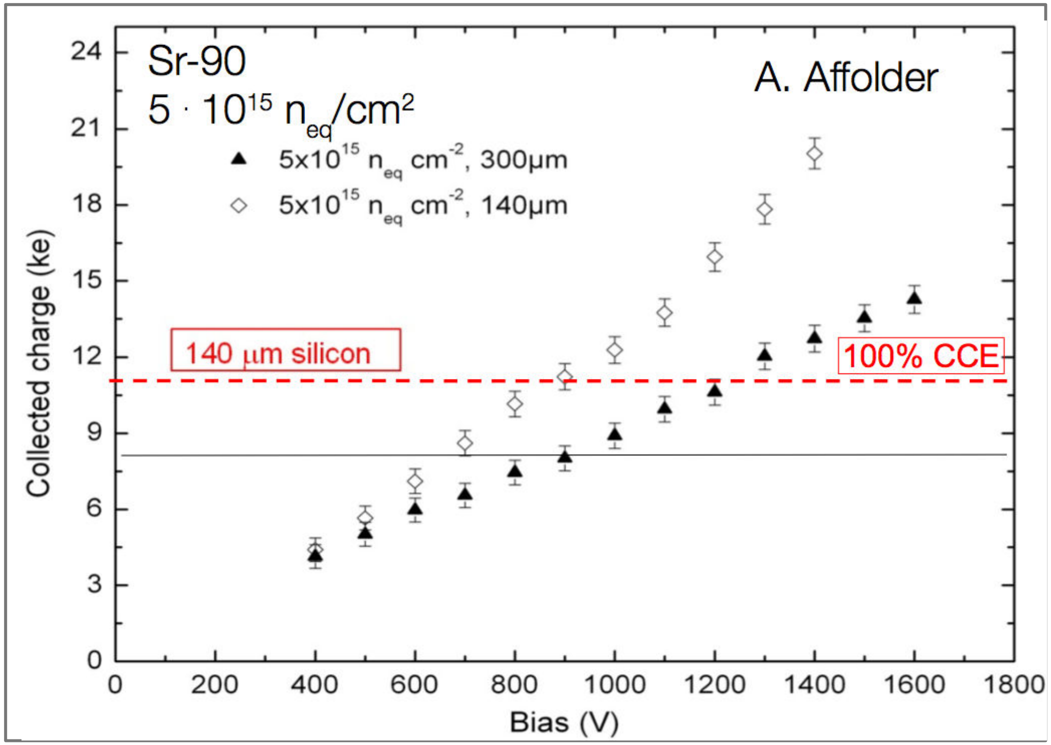
    Bonn, Carleton, CERN, Ljubljana, Ohio State, Toronto

- *Bring the 3 sensor technologies to the prototype phase for IBL*

Planar Sensors – Slim Edge

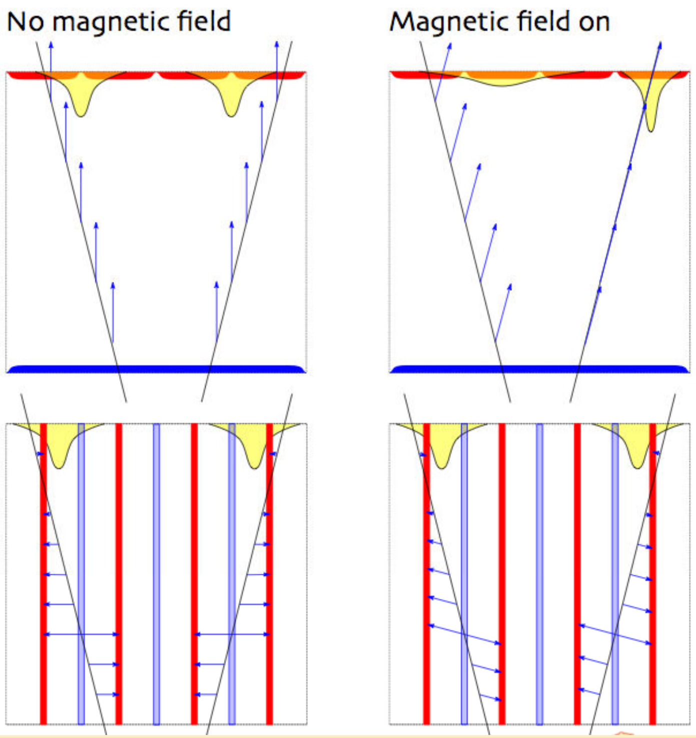
- *Planar sensor prototyping for IBL*
  - Large numbers of new results with strips and diodes (RD50) promise enough CCE for IBL

- *Parameter optimization under study*
  - Detector bias
    - Present pixel V_{bias}=600V, looking at implication of higher V_{bias} (1000÷1500V)
  - Optimize guard ring (geometrical inefficiency in Z) for slim edge
    - 300÷500 µm look feasible
  - Reduce thickness: more charge collected for given V_{bias}, lower bulk current
    - 250 is the standard, 200÷220 µm look feasible, 140µm would be attractive



3D Sensors - Test Beam

- *Jun.09 test beam: 1 ATLAS Pixel planar, 1 3D SINTEF/Stanford (full column), 2 FBK partial double columns (FBK 3EM5 has low breakdown @ 10V)*
- *For inclined tracks 3D sensors have similar efficiency and spatial resolution as planar – No Lorentz angle effect in 3D sensor*
- *Active edge (STA) show efficiency up to 5÷10µm from edge*

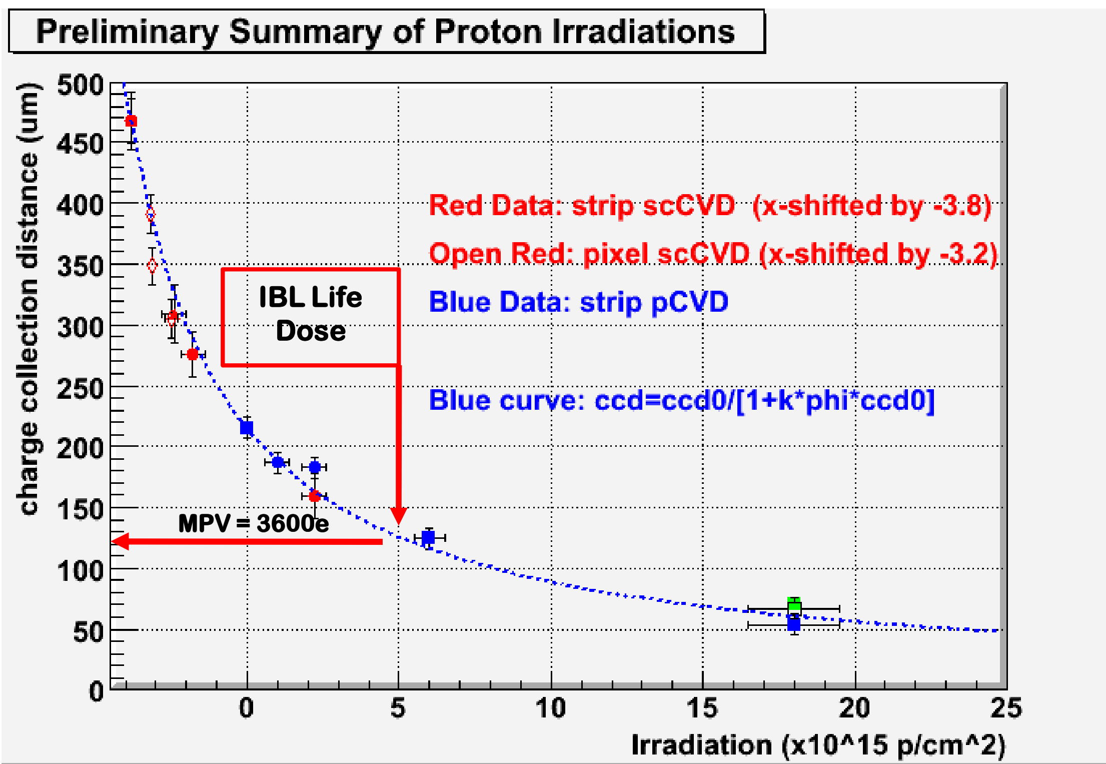


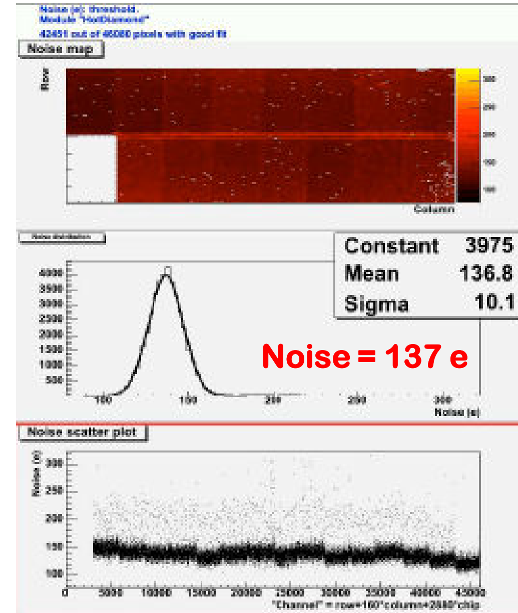
	Hit efficiency (%)		RMS (µm)			
	B = 0.0 T		B = 0.0 T		B = 1.4 T	
	$\phi = 0°$	$\phi = 15°$	$\phi = 0°$	$\phi = 15°$	$\phi = 0°$	$\phi = 15°$
Planar	99.9	99.9	13.8	9.7	10.2	10.4
STA 3E	96.7	99.8	14.3	10.8	13.9	9.8
FBK 3E7	99.0	99.8	14.0	10.4	13.5	9.7
FBK 3EM5	90.2	97.7	15.4	11.9	14.8	11.3

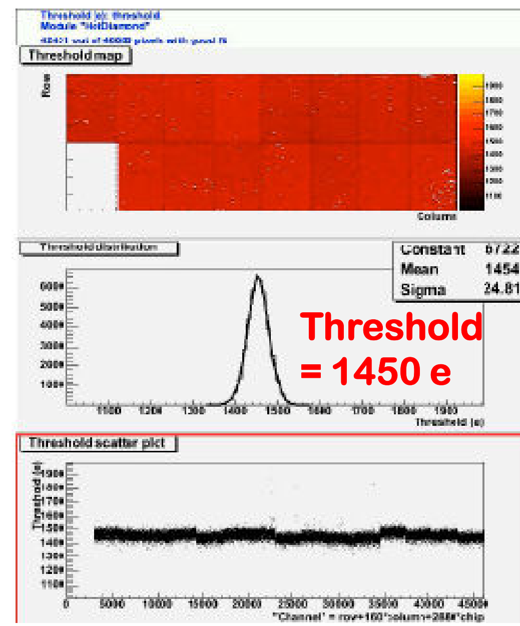
Ref.: O. Rohne – Vertex 2009

Diamond

- *Diamond advantages:*
  - Small capacitance → low noise (140e vs 180e of planar); possible lower threshold operation (1500e)
  - Operation with no cooling: no leakage current
- *Two modules built, more prototypes in 2010*





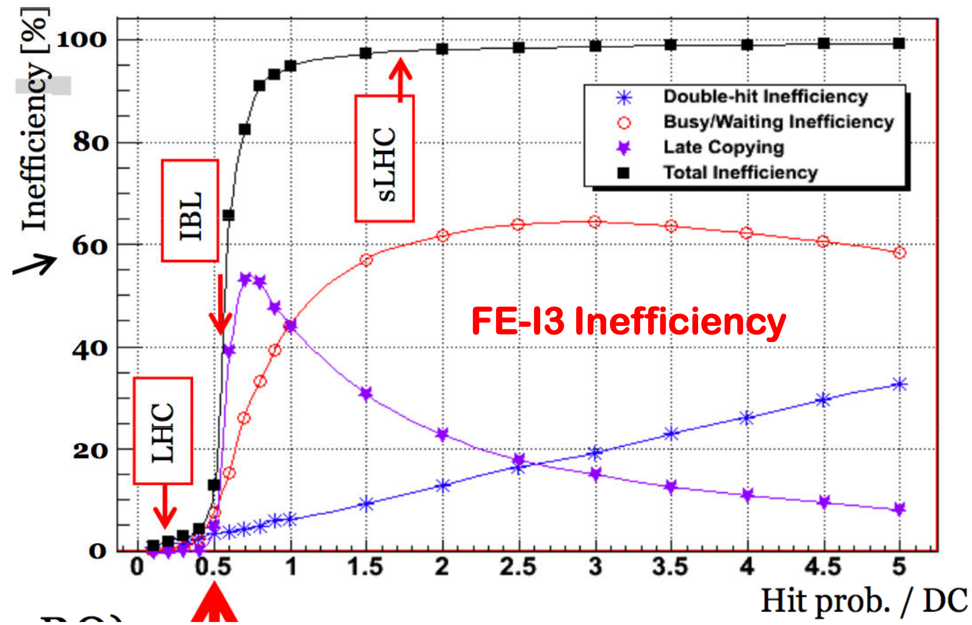


FE-I4

- *FE-I3 not suitable for IBL*
  - ~7% inefficiency at 3.7 cm and $\mathcal{L}$ = 3×10^{34} $cm^{-2}s^{-1}$
  - FE-I3 works at 50 Mrad, but has major faults at 100 Mrad

- *FEI4 design collaboration formed in 2007 between:*
  - Bonn, CPPM, Genova, LBNL, NIKHEF

- *FE-I4_proto chip (3/08)*
  - Main analog blocks ($3 \times 4 mm^2$)
  - Irradiated to 200 Mrad: noise increase by 20% (ENC 100→ 120 with 400fF load and I_{AVDD}=10μA/pixel)



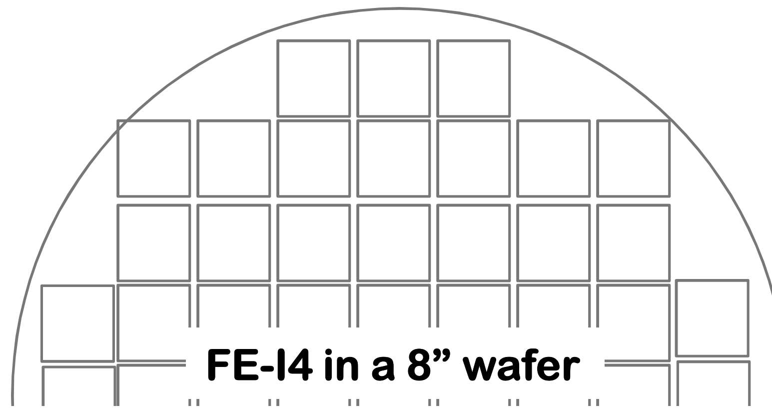
	FE-I3	FE-I4
Pixel Size [μm²]	50×400	50×250
Pixel Array	18×160	80×336
Chip Size [mm²]	7.6×10.8	20.2×19.0
Active Fraction	74%	89%
Analog Current [μA/pix]	26	10
Digital Current [μA/pix]	17	10
Analog Voltage [V]	1.6	1.5
Digital Voltage [V]	2	1.2
pseudo-LVDS out [Mb/s]	40	160

FE-I4: Review, Submission, Prototyping

- *FE-I4 submission review*
  - Review on “GDS II” ready
  - Nov 3-4 (K. Einsweiler to chair)
  - Submission, if review is passed, planned before the end of the year
- *Engineering run*
  - Up to 12 wafers from one engineering run (under investigation possibility of additional ones)
  - ~50 FE-I4 fit in a 8” wafer – yield “for good enough for module prototype” chip estimated 40÷70%
- *Planned prototypes with sensors by spring 2010*
  - Limited number of sensor options (max 3) for each of the three technologies
  - ~10% of IBL in prototyping size
  - 200÷300 FE-I4 dedicated for module prototype

Review team:

Francis Anghinolfi, CERN - Stéphane Debieux, Geneva (IBL Electronic Project Engineer) - Kevin Einsweiler, LBNL (Review Chair) - Philippe Farthouat, CERN (Project Office) - Alex Grillo, UCSC - Kostas Kloukinas, CERN - Xavier Llopart, CERN - Mitch Newcomer, Penn - Ivan Peric, Heidelberg - Ned Spencer, UCSC - Mike Tyndel, RAL (Project Office) - Rick Van Berg, Penn



FE-I4 Design Collaboration

[1]**Bonn**
Michael Karagounis, Tomasz Hemperek, Andre Kruth

[2]**CPPM**
Mohsine Menouni, Denis Fougeron

[3]**INFN Genova**
Roberto Beccherle

[4]**LBNL**
Abder Makkaoui (lead designer), Dario Gnani, Julien Fleury (visitor)

[5]**NIKHEF**
Ruud Kluit, Jan-David Schipper, Vladimir Gromov, **Vladimir Zivcovic**

Physicist/Students (specification, testing, etc)
D. Arutinov[1], M. Barbero[1], G. Darbo[3], S. Dube[4], D. Elledge[4], M. Garcia-Sciveres[4], A. Rozanov[2]

Stave & Thermal Management

- *Stave design goals:*
  - Reduction of material budget from Pixel (2.7 % $\rightarrow$ 1.5 % of X_0): Carbon Foam
  - Carbon Fiber (CF) pipe (no corrosion, CTE match) and Titanium (Ti) pipe prototypes:
    - 2mm OD (for CO_2 cooling), 3mm OD (for C_3F_8 or CO_2) and 4mm OD.
  - Thermal figure of merit (ΔT between module and pipe internal wall) of staves and pipes under measurements
  - High pressure test (150 bar for CO_2) passed by CF and Ti pipes
  - Fittings and pipe splicing under development

- *Cooling:*
  - Prototyping CO_2 and C_3F_8 cooling system in cooperation with ATLAS CERN cooling groups and NIKHEF
  - IBL mock-up to confirm thermal simulation of beam-pipe bakeout

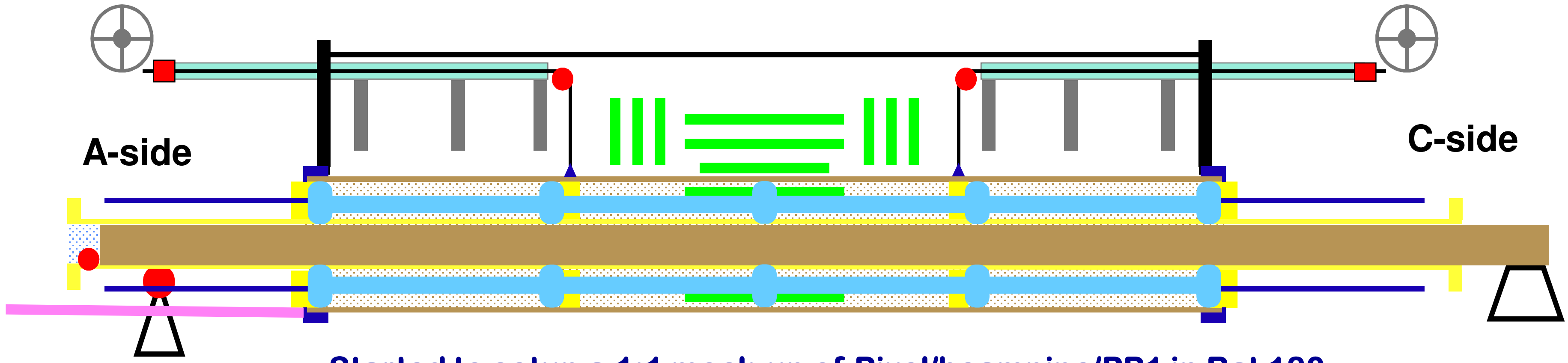
Stave Material Budget

"Invariant Contributions"	**X0 [%]**	
Silicon sensor (250um)	0.27	
FE chip	0.33	
Flex circuit	0.2	
Stave foam (4mm with X0=426cm)	0.09	
Carbon facings (2x200um)	0.13	
Total invariant	***1.02***	
"Cooling contribution"		
CO2 pipe 1.5mm ID		
C3F8 pipe 3.0mm ID	C02	C3F8
Coolant fluid (liquide 80/60%)	0.03	0.13
Cooling pipe CF (300um)	0.04	0.07
Cooling pipe Ti (120um)	0.12	0.22

Credits: D. Giugni, P. Schwemling, H. Pernegger

Installation Scenarios

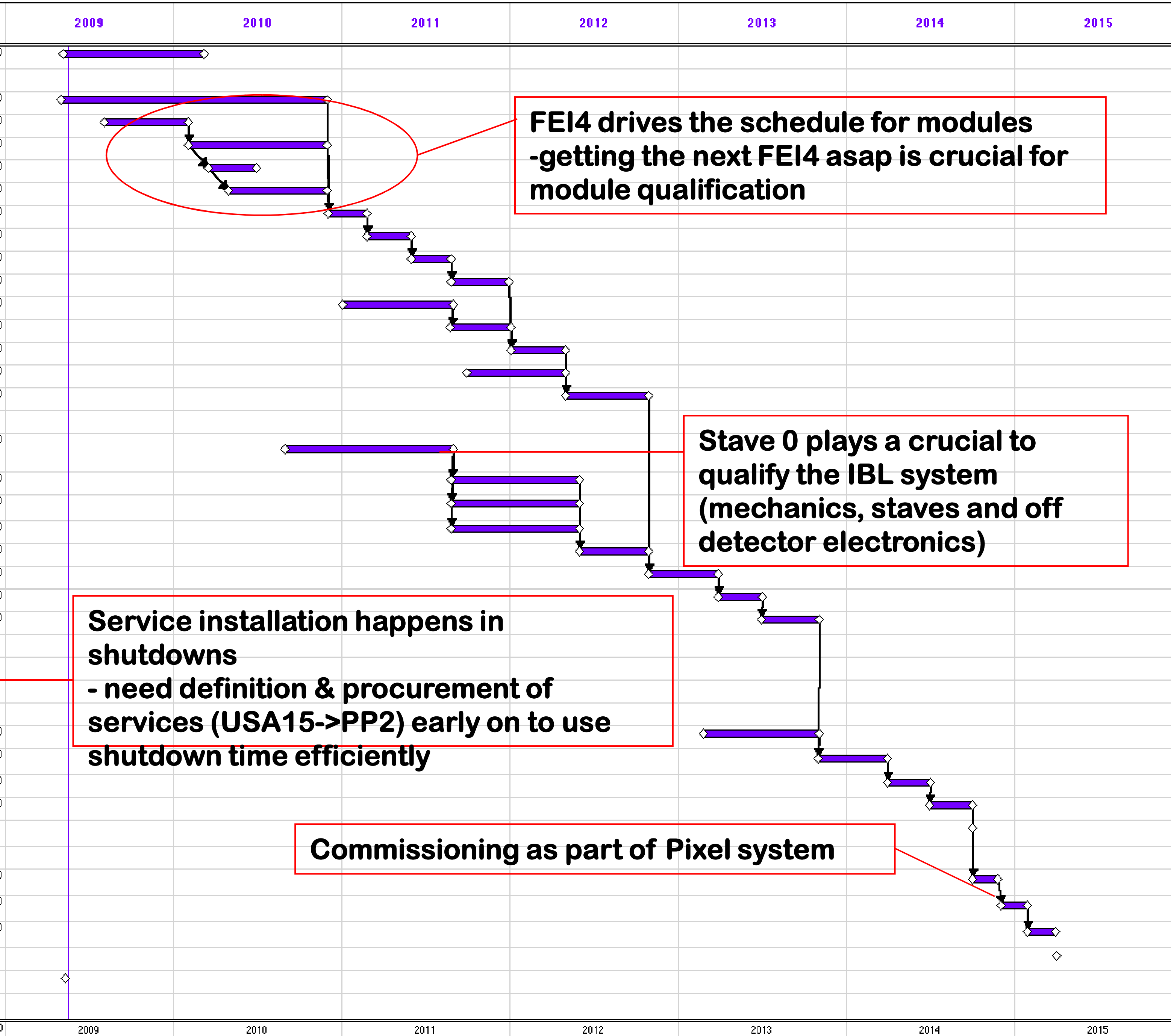
- *Two global support / installation scenarios: IBL support tube (1) / no tube (2):*
  - An IBL support tube would have advantage on stiffness and simplicity/safety for IBL installation, but drawback are envelope needs (~1÷1.5 mm) and increase of radiation length
- *Procedure studied on mock-up at bld.180 - procedure (1) animation:*
  - The beam pipe flange on A-side is to close to the B-layer envelope - Need to be cut on the aluminum section
  - A structural pipe is inserted inside the Beam Pipe and supported at both sides.
  - The support collar at PP0 A-side is disassembled and extracted with wires at PP1.
  - Beam pipe is extracted from the C-side and it pulls the wire at PP1
  - New cable supports are inserted inside PST at PP0.
  - A support carbon tube is pushed inside the PST along the structural pipe.



Started to setup a 1:1 mock-up of Pixel/beampipe/PP1 in Bat 180

R. Vuillermet

Activity Name	Start Date	Finish Date	Duration (Work Days)
TDR	5/5/09	3/8/10	220.00
Modules			
Sensor qualification (irrad)	5/1/09	11/30/10	413.00
FE I4 prototype prod	8/4/09	2/1/10	130.00
FE I4 prototype tests	2/1/10	11/30/10	217.00
Module 0 assembly	3/18/10	6/30/10	75.00
"Module 0" qualifaction	4/29/10	11/30/10	154.00
IBL FE I4 Eng. Run	12/1/10	2/24/11	62.00
IBL FE I4 Eng Testing	2/24/11	5/31/11	69.00
FE I4 Prod	6/1/11	8/25/11	62.00
FE I4 Prod Test QA	8/25/11	12/30/11	92.00
Sensor Production	1/3/11	8/31/11	173.00
Sensor testing	8/23/11	1/2/12	95.00
Bump bonding	1/2/12	5/1/12	87.00
HDI	9/29/11	5/1/12	154.00
Module assembly and QA	5/1/12	10/29/12	130.00
Stave			
Stave 0 prototyping and tests	8/31/10	8/30/11	261.00
EOS card	8/25/11	5/30/12	200.00
Internal services prod	8/25/11	5/30/12	200.00
Stave production	8/25/11	5/30/12	200.00
Stave assembly and QA	5/30/12	10/29/12	109.00
Module Loading and test	10/29/12	3/29/13	110.00
Final Stave QA	3/29/13	7/1/13	67.00
Contingency	7/1/13	11/1/13	90.00
Integration and Installation			
PP and opto installation			
Service installation			
Extraction			
Global support	2/25/13	11/1/13	180.00
Stave mounting & internal services	11/1/13	3/31/14	107.00
IBL Surface test	3/31/14	7/1/14	67.00
Continency	7/1/14	9/30/14	66.00
Installation IBL	10/1/14		
Commissioning (tbc)			
Service connection and verification	10/1/14	11/25/14	40.00
IBL integration to Pixel and IBL calibration	12/1/14	1/28/15	43.00
Pixel Combined Tested in ATLAS with IBL	1/28/15	3/31/15	45.00
Ready for Datataking	4/1/15		
Off detector (to be detailed)..	5/10/09		
Irradiation & TB (to be detailed)			
			3,918.00



Schedule

- *We plan to be ready for installing by end 2014:*
  - Cannot be ready much before without sacrificing performance:
    - need new technology development (on going) and prototyping (next year) for FE-I4 (more radiation hard, R/O efficiency), Sensors (more radiation hard), Staves (lighter).
  - IBL, in addition to take over the B-layer when accumulated dose will reduce its efficiency, will improve the present tracking performance (lighter and at small radius than present B-Layer) and will be an insurance for hard failures (cooling, opto-links, interconnections, etc.) of present B-layer.

- *To install the IBL we need a long shutdown (8 months):*
  - Need to synchronize a long shutdown (8 months) for IBL installation – this could be in the "shadow" of machine element installation

- *The IBL is in the roadmap of the new Pixel detector at sLHC*
  - The technologies needed for the IBL are either usable for Pixel outer layers or are a first step toward more radiation hard and higher R/O bandwidth components for the inner Pixels.

Implications of IBL

- *IBL will impact other components of the LHC machine and ATLAS*
  - Smaller beam-pipe and larger aperture new triplets (sLHC phase I) require to revisit the TAS and the forward shielding

- *Larger aperture triplet and new TAS design requires to look at:*
  - Effects on muon background;
  - Protection of a smaller radius IBL.

- *Also, we have other beam-pipe issues, like going to much longer beryllium sections.*
  - This is not strictly sLHC phase I, but has same timescale.

Conclusions

- *IBL organization structure well in place*

- *TDR and MoU in progress – project cost evaluated*
  - Motivated groups and Institutes support

- *Challenging project:*
  - Tight envelopes, material budget reduction, radiation dose and R/O bandwidth requirements

- *New technologies in advanced prototype phase:*
  - Sensors, FE-I4, light supports, cooling

- *Ready for installing in 2014 together with a smaller beam pipe*
  - It is not just a “replacement of existing B-layer”, but it improves performance for b-tagging and it is an assurance for hard failures of present B-layer