Experiences with the ATLAS Pixel Detector Optolink and Researches for Future Links

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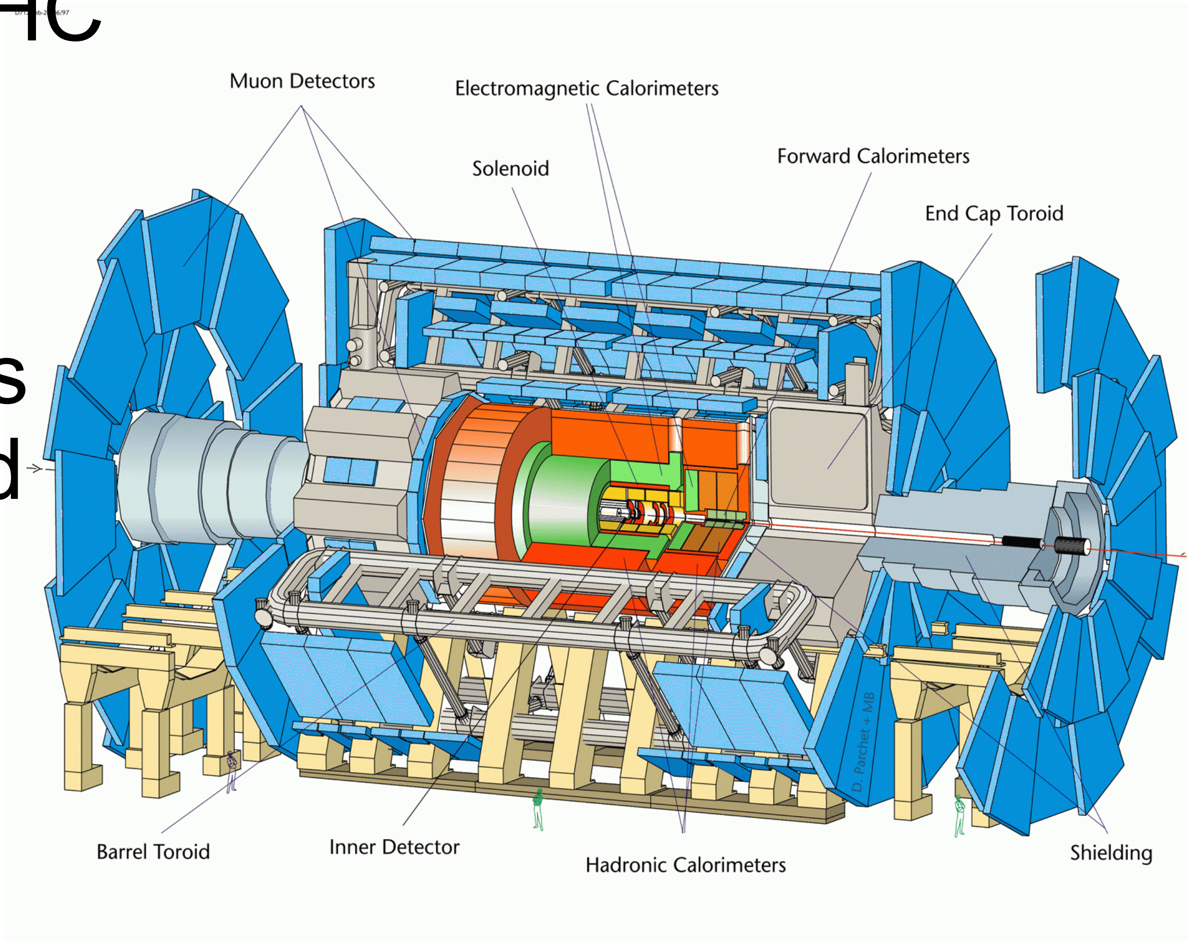
Outline

- Introduction to ATLAS Pixel Optolinks
  - Components
  - Variables
- Lessons learned from Layout, Production and Operation
- Future Plans
- Conclusions

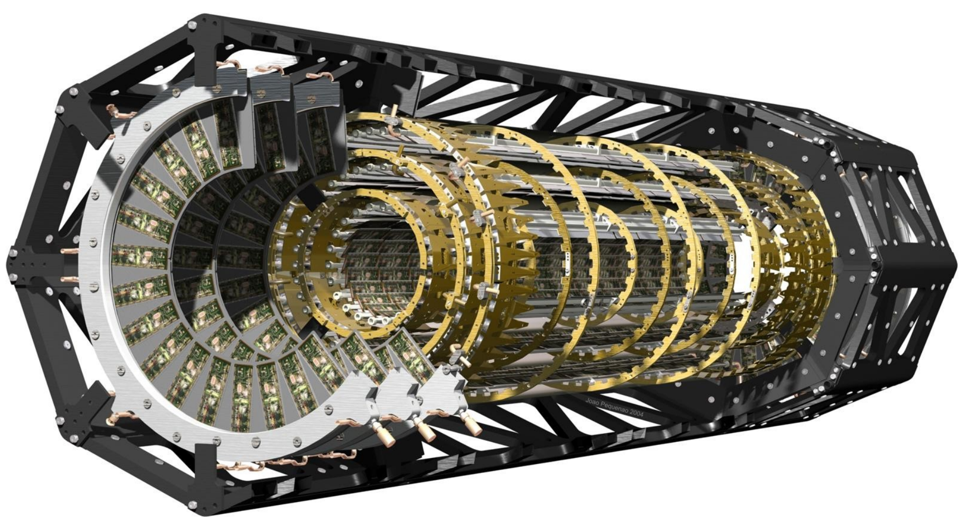
ATLAS

- General purpose LHC experiment
- 40 MHz BC rate
- Innermost detectors are silicon pixel and strip systems



Pixel Detector

- Min. 3 space points per track, up to $\eta = 2.5$
- ~14 µm resolution in $R\varphi$, ~112 µm in z
- Triggered readout at 75 kHz
- 1744 detector modules in total

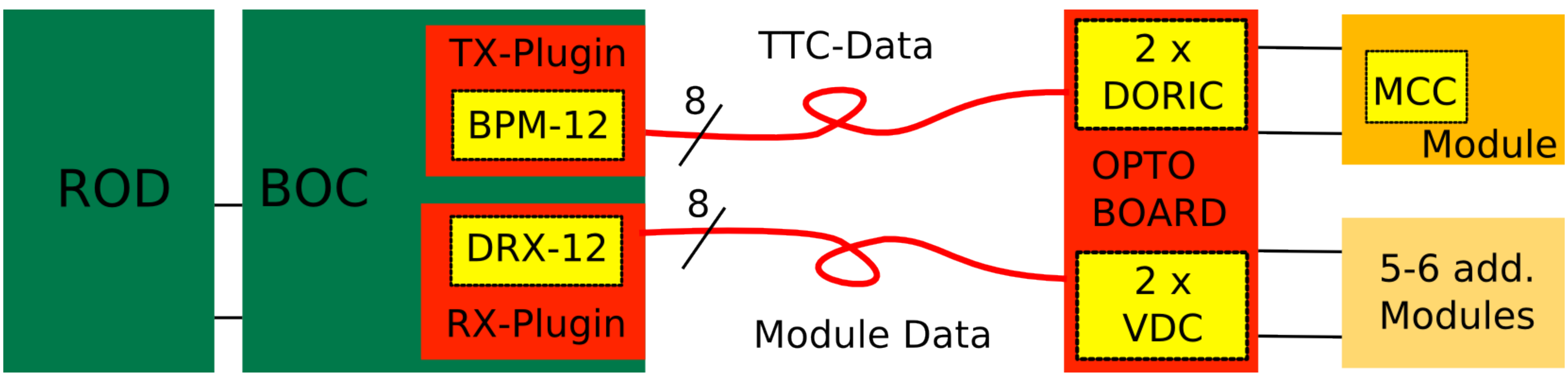


The ATLAS Pixel optical Readout Requirements

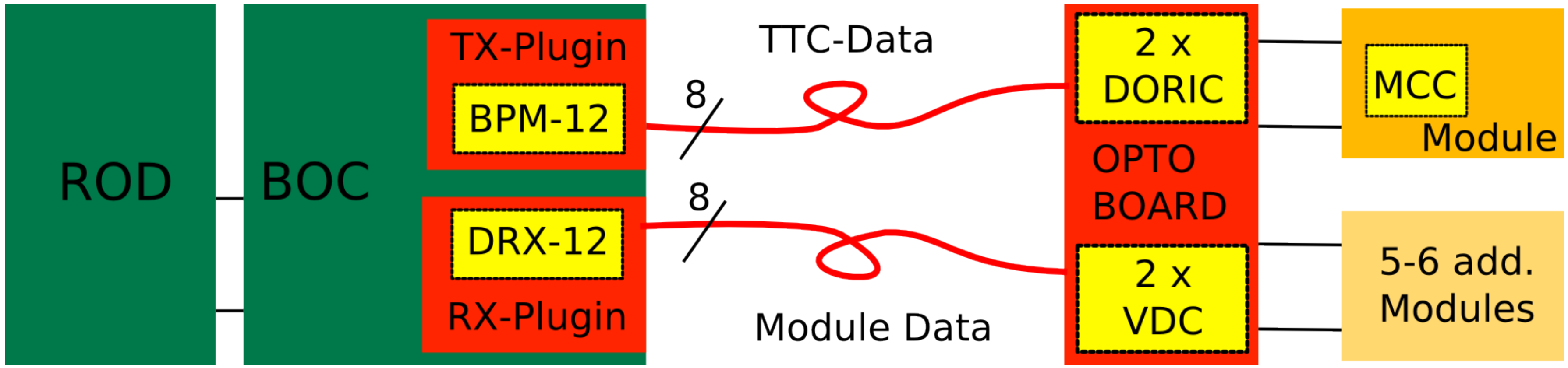
- Speed: 80 MBit/s at max. per link
- Timing: < 1 ns adjustable phase shift between modules to optimize physics performance
- Low Latency command line:
  - Readout buffers in modules can only keep 255 clock-cycles (~6.4 us)
- Stable operation:
  - Parameters should “at least” not need adjustment during one run

The ATLAS Pixel optical Readout

- Per-module Readout (1744 links)
- Bundled per half-stave (6 / 7 modules) or disc-sector (6 modules) for electro-optical conv.
- 1 / 2 data links per module, depending on the geographical position (occupancy)



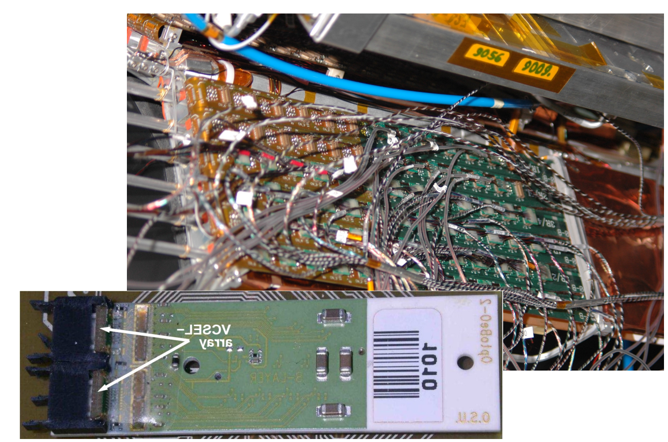
The ATLAS Pixel Optical Readout



Off-Detector optical components

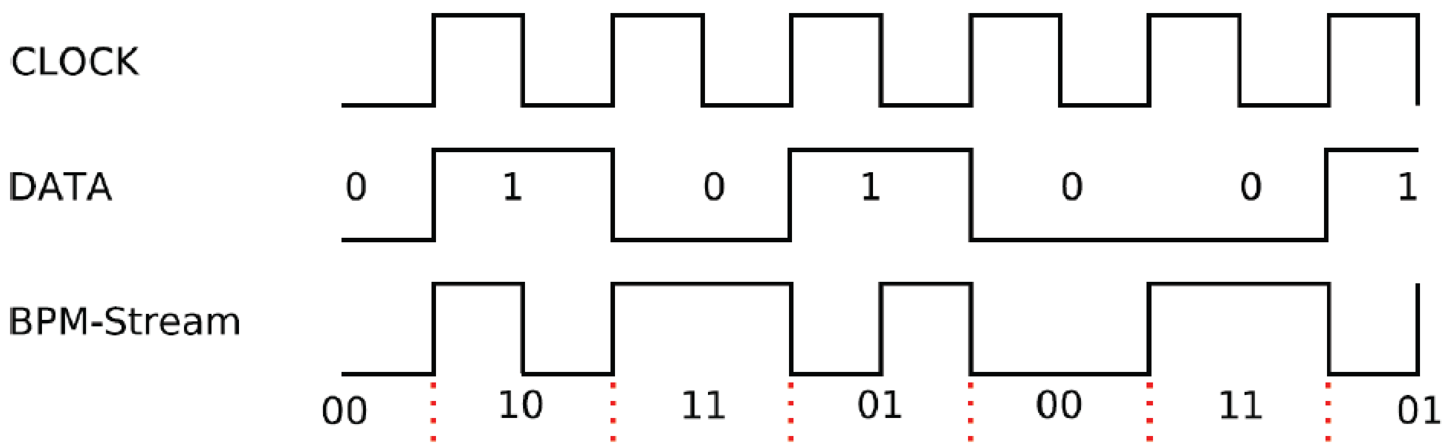
80m Fibre

On-Detector optical components



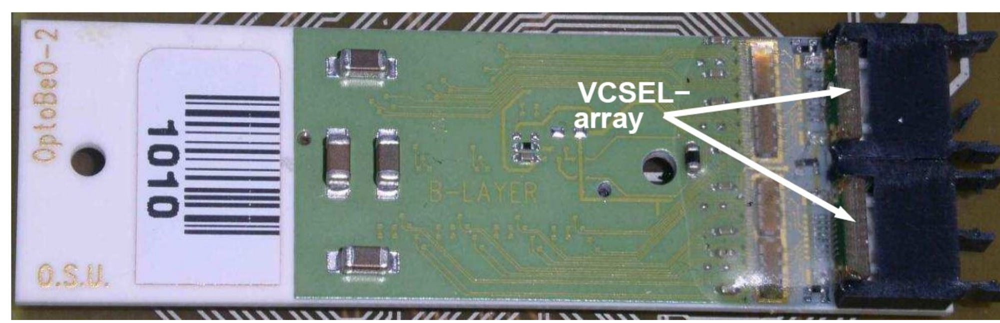
Off-Detector TTC transmitter: The TX-plugin

- 8 Channels
- Encodes Clock & Data per module into a single stream using BiPhase Mark encoding (Latency about 65ns)



On-Detector Receiver and Transmitter: Optoboard

- Receives up to 8 BPM-encoded optical streams and decodes them into clock and data per mod.
- Transmits data of at max. 8 modules back to the off-detector electronics
- Up to 16 return links, depending on the geographical position of the corresponding modules
- One common power control per Optoboard



Off-detector Receiver: RX-plugin

- 8 PiN channels receiving data
- No active decoding needed
- Threshold PiN current adjustable: 0 – 255 µA

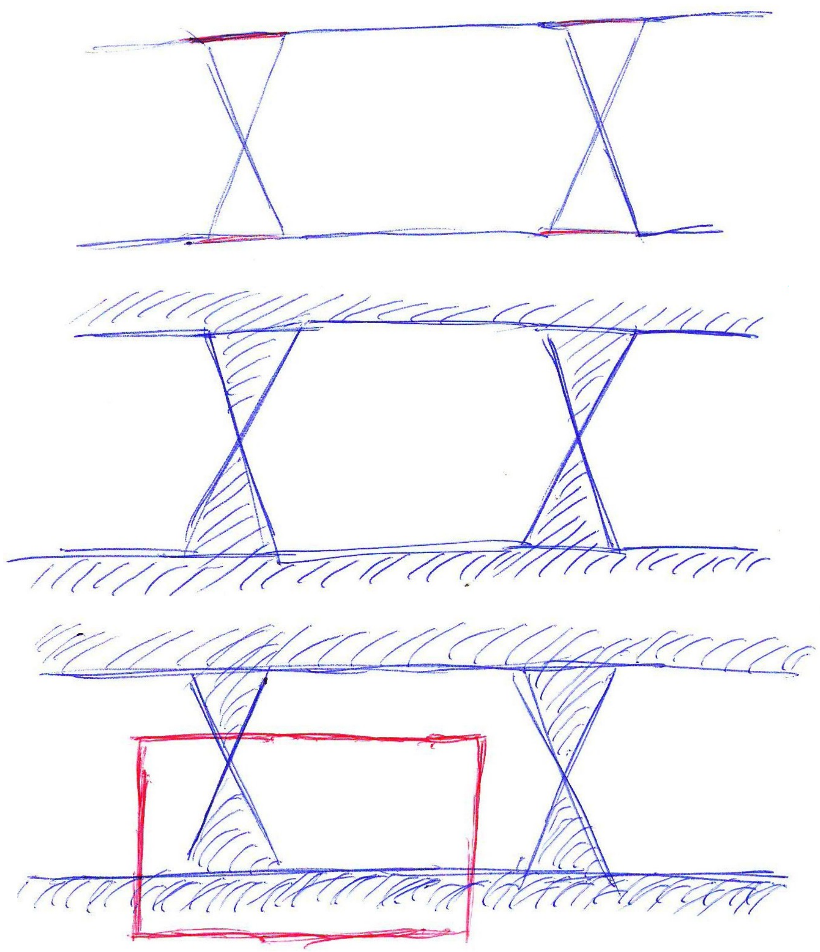
Variables of the System

Need individual tuning...

- TX-plugin, per chan.:
  - Light power
  - *Mark-to-Space Ratio*
  - Coarse delay (25ns/step)
  - *Fine phase* (~300ps/Step)
- Optoboard:
  - V_{iset} *(light Power)* per Optoboard (!)
- RX-path, per Chan.:
  - *Threshold current*
  - *Delay (phase)* (0-24ns, 1ns/step)

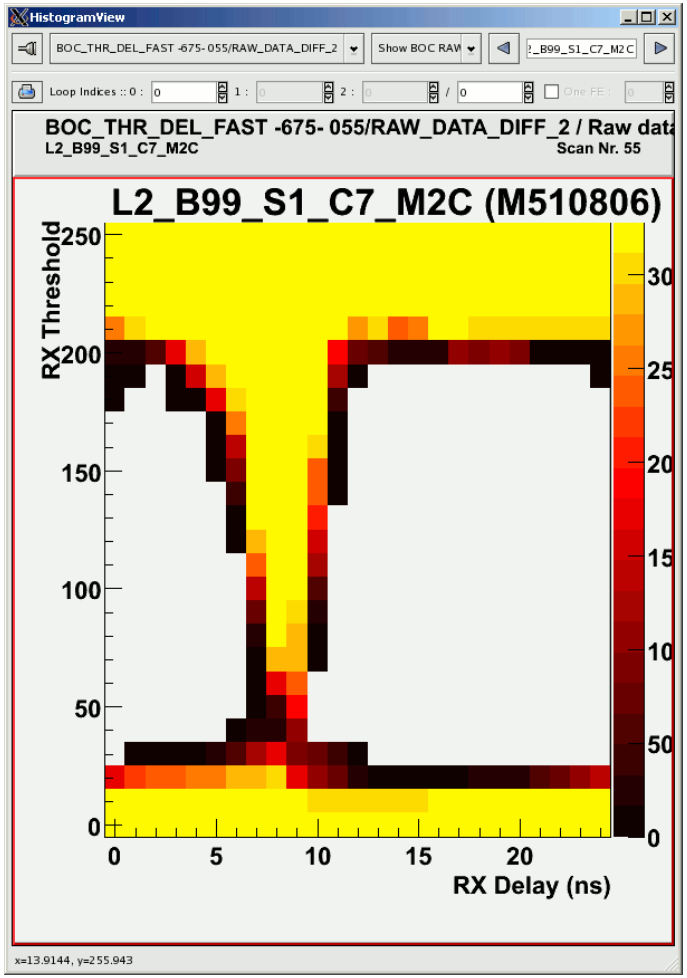
Small Intro to BocScans...

- Take an "eyepattern"
- Apply white to the inside, something else to the outside
- Select one clock cycle of phase space and a fixed range in signal height
- Phase needs to be inverted as the scans shift data instead of sampling clock



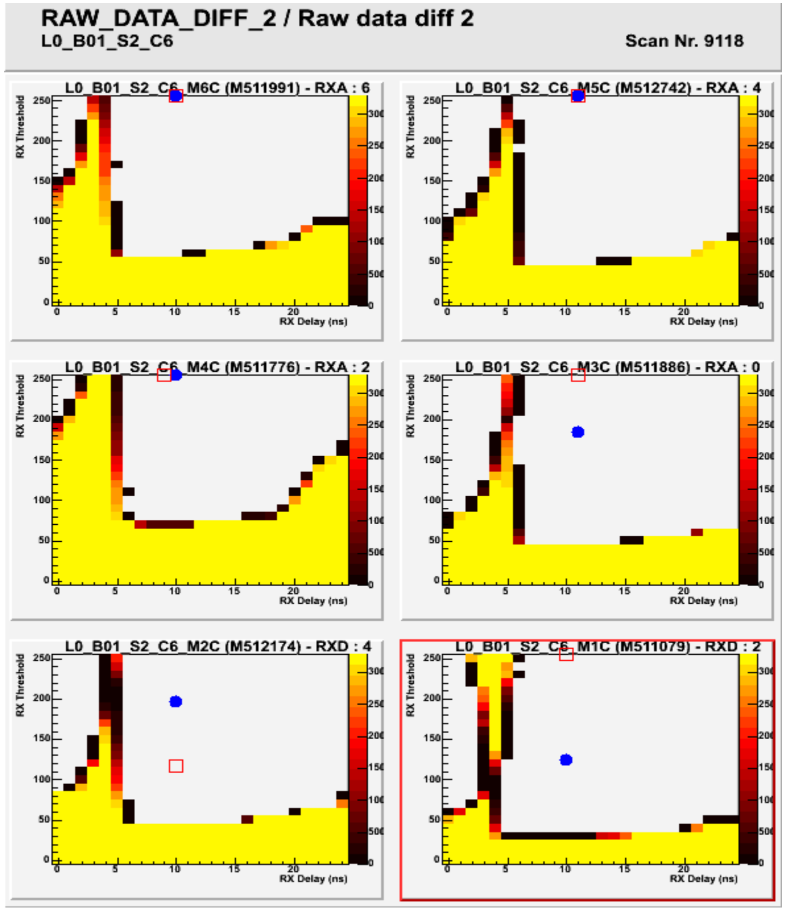
And the resulting BocScan...

- Threshold: 26 Steps (10 uA)
- Delay: 25 Steps (1 ns)
- Signal is stable and delivers sub-ns resolution if wanted
- Signal height corresponds to signal amplitude (power)
- Works and delivers good results...



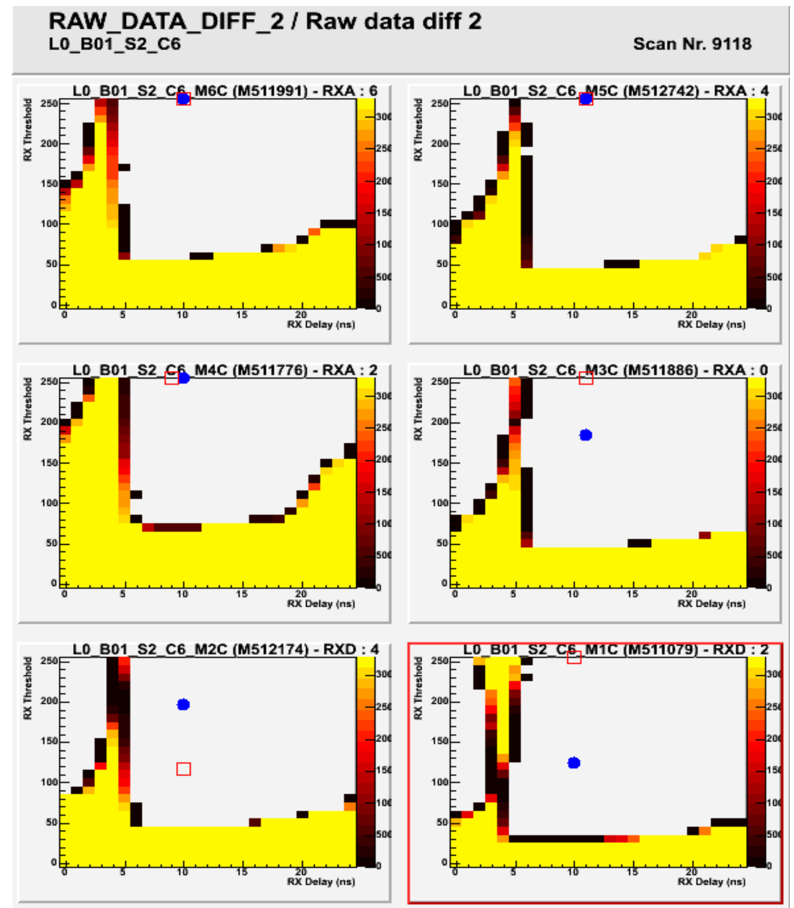
Problems (Layout): Lack of DC-balancing

- RX-links have unbalanced transmission
- Thresholds and phases need to “manually” be adjusted off-detector
- Software exists, but keeps struggling with “special” links



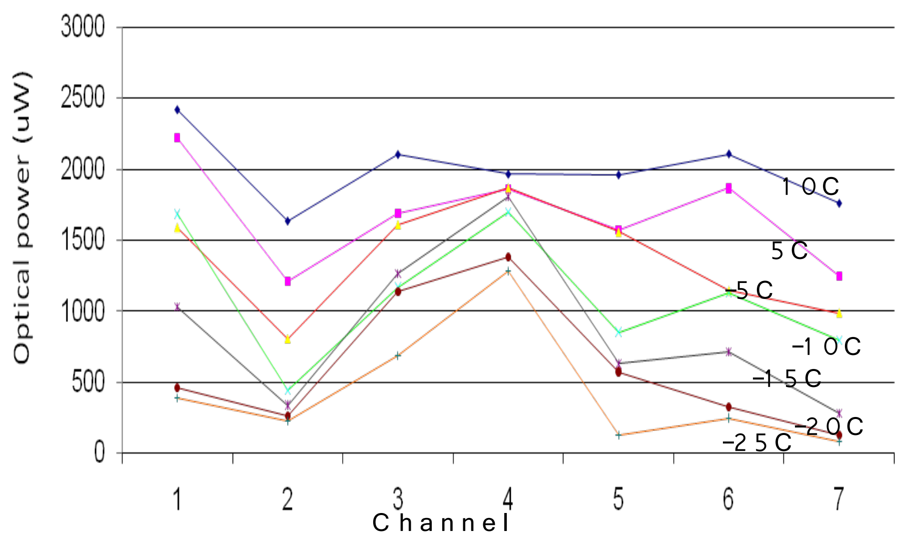
Problems (Layout): RX-plugins designed for lower P

- Light powers incoming are very high, compared to the maximum threshold
- Optoboards thus need to be operated near laser threshold
  - Unstable
  - Gives large differences for individual channels
- Irradiation “heals” this...



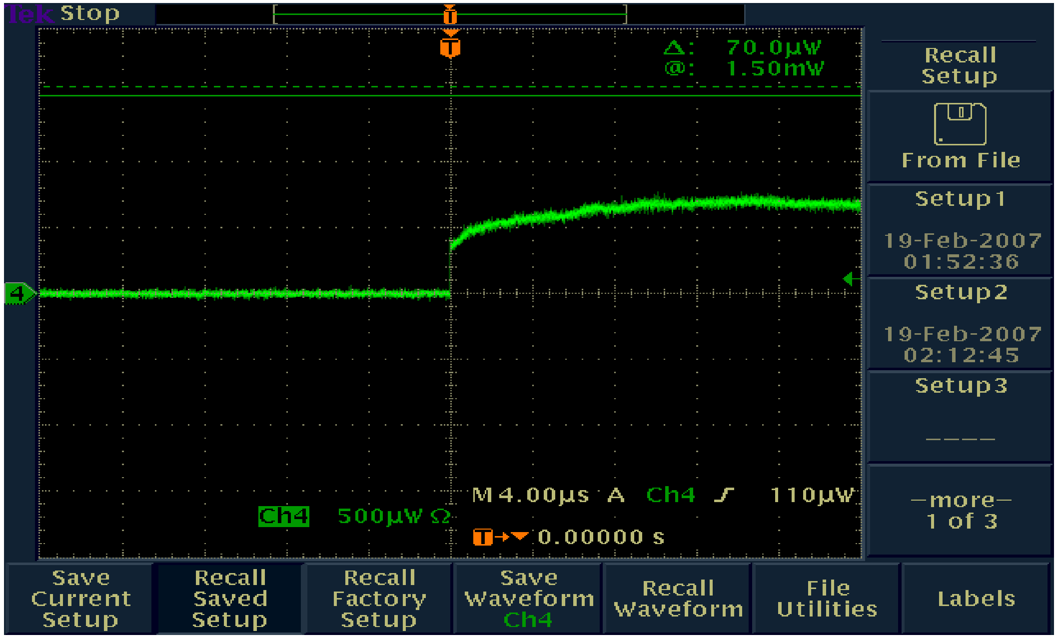
Problems (Layout): "Freezing" LASERs

- Optoboard lasers were optimized for operation at ~20C
- Typical operation point without additional heating at ~5C (Heating was added...)



Problems (Layout): Control of thermal conditions

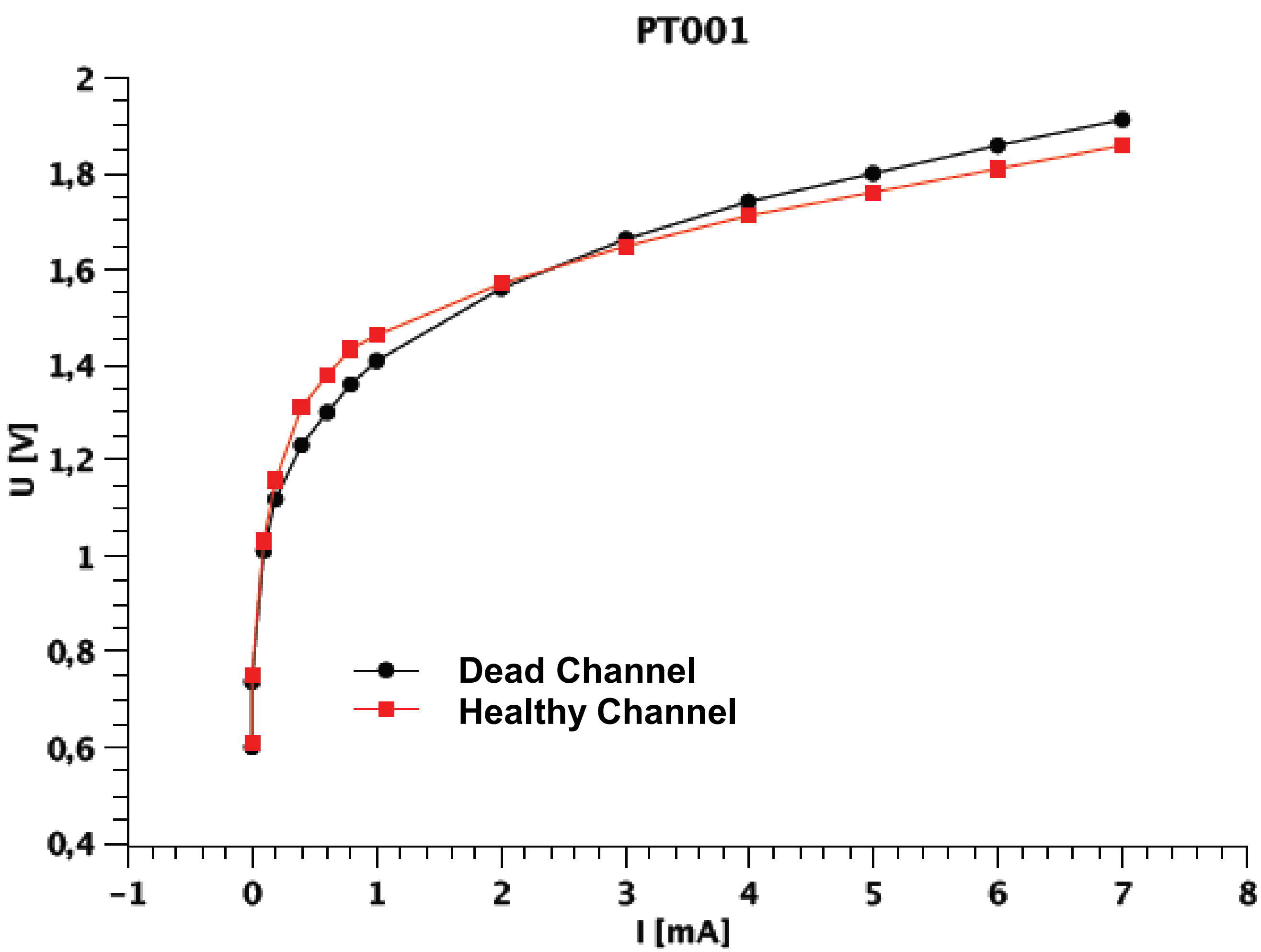
- Cooling lasers down to 5C most of them still have an appropiate light power
  - Tuning the links using a clock-like return pattern works out beautifully
- Using real data (not 50% on) a signifikant change in the tuned operational para-meters is observed: Slow TurnOn



Problems (Production)

- TX-plugins suffer from ESD damage, which can only be observed by measuring the IV characteristics of the laserdiode (dismounted):
  - Significantly lower knee voltage
  - Different slope in conducting region
- Affected plugins show no light output after running for a while (where “while” depends on the ESD voltage)
- Parts of the system were exchanged so far (~30 channels in a total of ~15 plugins died)

IV-Curves


PT001
2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
U [V]
−1
0
1
2
3
4
5
6
7
8
I [mA]
Dead Channel
Healthy Channel

Weak Points: What we learned...

- Concerning the layout:
  - Data link not DC-balanced
  - RX-plugins designed for lower input power
  - Optoboard lasers “freeze” (Solution: Heating)
  - Thermal conditions on-detector are not consistent with design and hardware constraints
- Concerning production:
  - TX-plugins suffer from ESD damage

Future Plans

- Lessons learned to be taken into account:
  - Next link to be fully DC-balanced
  - Single High-Speed links per multiple modules (?)
  - On-detector clock generation and fine-phase adjustement (?)
  - In-system IV-curve measurement possible
- First components for setting up a laser test setup arrived
  - Thermal properties of lasers including packaging to be characterized

Conclusions

- The ATLAS Pixel Optolink generally works, even though it sometimes makes life hard...
- An update would be appreciated, and is needed for SLHC anyways
  - Maybe used for the ATLAS ID upgrade ~2013

Backup ahead...