Prototyping Serial Powering with RD53A

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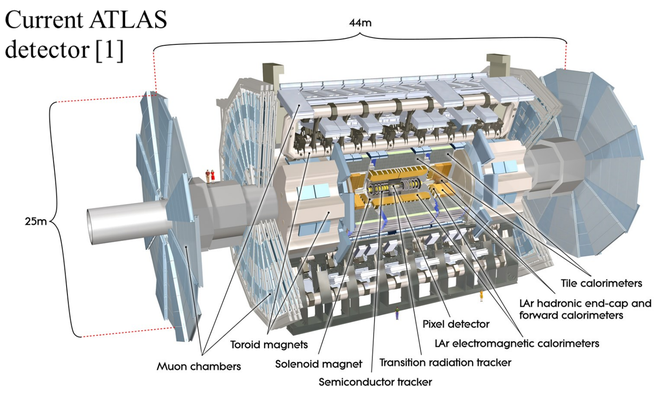
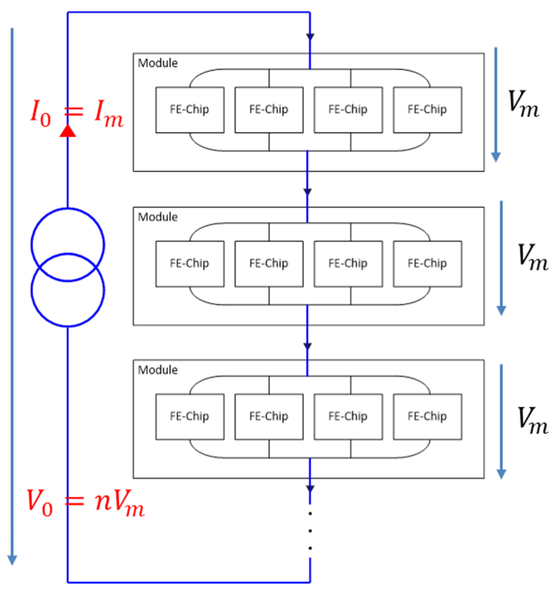
ATLAS Phase-II Upgrade LHC & ATLAS





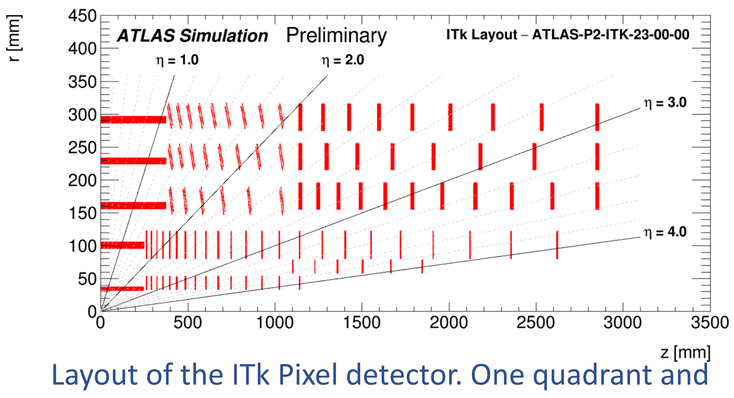
Simpified schematic of the serial powering scheme. Here, each module consists of 4 read-out chips connected in parallel, each equipped with 2 Shunt-LDOs

New ATLAS pixel detector for the HL-LHC

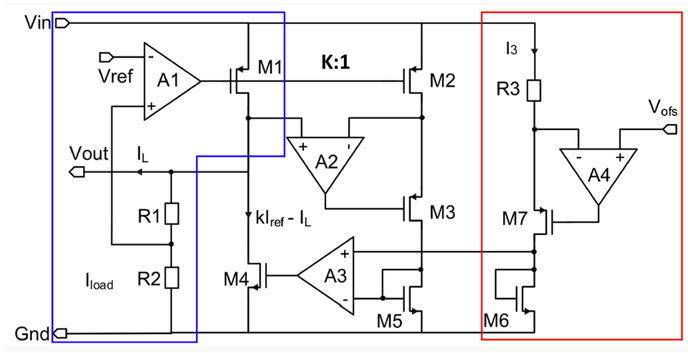
- Instantaneous **luminosity increases** by factor of 5 - 7.5
- Requires detectors with **better radiation tolerance** and **higher rate capabilities**
- New pixel detector as part of an **all-silicon tracker** (ITk)
- **5 layers of pixellated sensors** extending over 6 m in z and 70 cm in R, ~15 m² surface area
- **Hybrid pixel detector** with 3D and planar sensors

Serial Powering Scheme and Shunt-LDO Regulator

- **Reduce power** loss in services and **material budget**
- Up to **14 modules** in series supplied by **constant current**
- **New** powering scheme, requires extensive **prototyping**
- **On-chip Shunt-LDO** [3] generates front-end supply voltage from constant input current
- Electrical characteristic follows **ohmic resistor** in series with an **offset voltage**
- For further Shunt-LDO developments, see J. Kampkötter's poster (ID: 575)

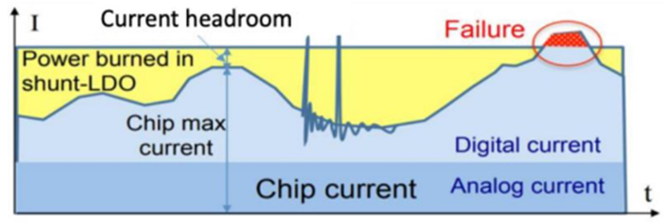


Layout of the ITk Pixel detector. One quadrant and only active elements are shown. [2]



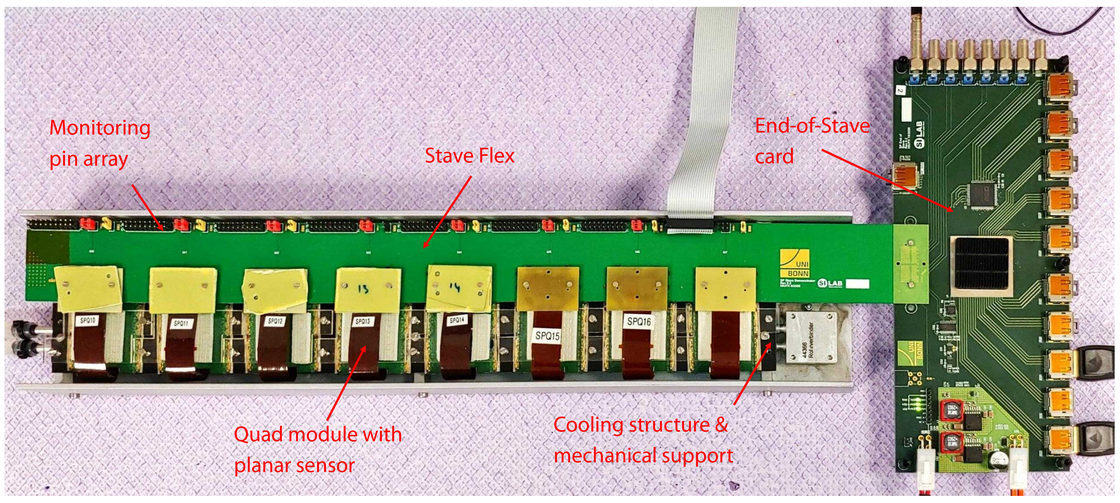
Top: simplified schematic of the Shunt-LDO regulator.

Bottom: Current headroom in a Shunt-LDO



RD53A Serial Powering Chain with Planar Quad Modules

- **Prototype** to study **low-level system aspects** on a small, accessible setup
- **Serial powering chain** of 8 RD53A [4] quad-chip modules with **planar sensors**, can be daisy-chained for longer chains
- **Dedicated** module flex and services, offering additional **test points** and **configurable** data routing & HV distribution
- System readout using the **BDAQ53** [5] DAQ system
- Services for follow-up setup with **ITkPix quad modules** available



A serial powering chain with 8 RD53A quad modules on a mechanical support. Module flexes, stave flex and End-of-Stave card are special designs with extra diagnos-

Summary & Outlook

- A **serial powering prototype** using **RD53A quad modules** set up in Bonn. Preliminary **results** look very **promising**. **Loading** of stave with **ITkPix** quads in **near future**
- Setup with **ITkPix** quad modules will be **used in larger scale system tests** to provide important **input** for ITk Pixel **system specifications**.

References

[1] Joao Pequenao, "Computer generated image of the whole ATLAS detector", URL: https://cds.cern.ch/record/1095924

[2] URL: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/ITK-2020-002/fig_02.png

[3] Michael Karagounis et al., *An integrated Shunt-LDO regulator for serial powered systems,* ESSCIRC'09 Conference, Athens, Proceedings of ESSCIRC'09, 276

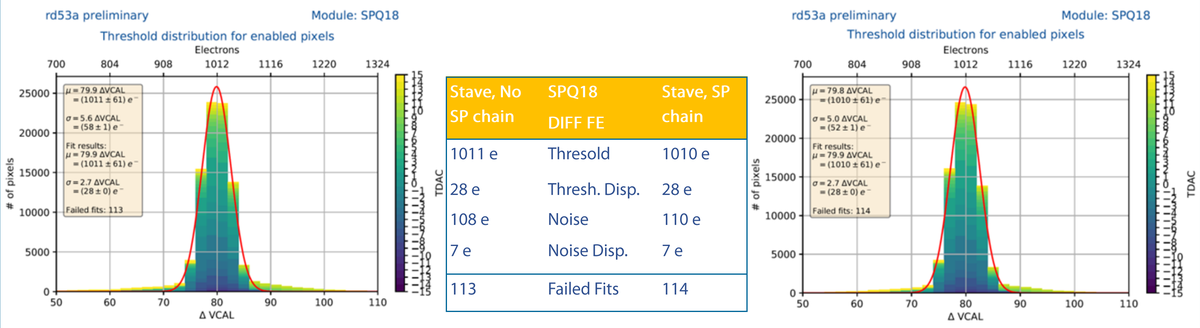
[4] RD53 Collaboration, *Development of pixel readout integrated circuits for extreme rate and radiation,* CERN-LHCC-2013-008 (2013)

[5] Michael Daas et al., *BDAQ53, a versatile pixel detector readout and test system for the ATLAS and CMS HL-LHC upgrades*, Nucl.Instrum.Meth.A 986 (2021) 164721

RD53A Serial Powering Chain Characterization

Different characterization aspects: Module performance, electrical characteristics, potential failure scenarios & undesirable behaviour

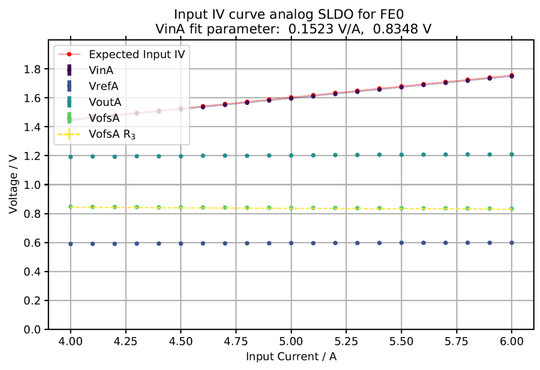
Good module yield: 1 module with a broken Shunt-LDO, 1 module with untunable front-end



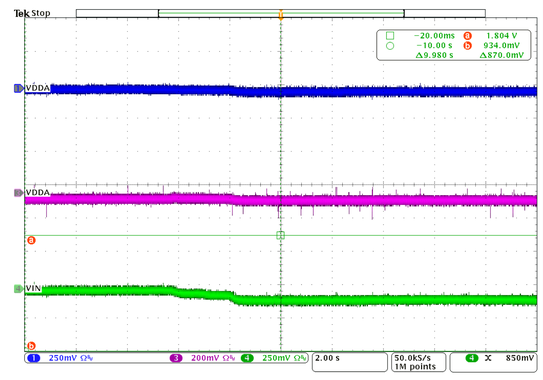
Stave, No SP chain	SPQ18 DIFF FE	Stave, SP chain
1011 e	Thresold	1010 e
28 e	Thresh. Disp.	28 e
108 e	Noise	110 e
7 e	Noise Disp.	7 e
113	Failed Fits	114

Module performance: Following expectation. Key figures agnostic to system layout (e.g. HV scheme). Example comparing standalone operation with serial chain.

Electrical characteristics: Mostly compatible with expectations. **Target working point** of **1.5 V @ 4.5 A** reached. **Offset not matching** target offset $V_{Ofs,t}$ = 0.9 V. Underlying **Shunt-LDO** issues **fixed** for **RD53B**.



Estimate required module current to prevent Shunt-LDO overload. **Target working point** includes **20 %** current **headroom.** During overload, Shunt-LDO output voltages & module voltages drop significantly.



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