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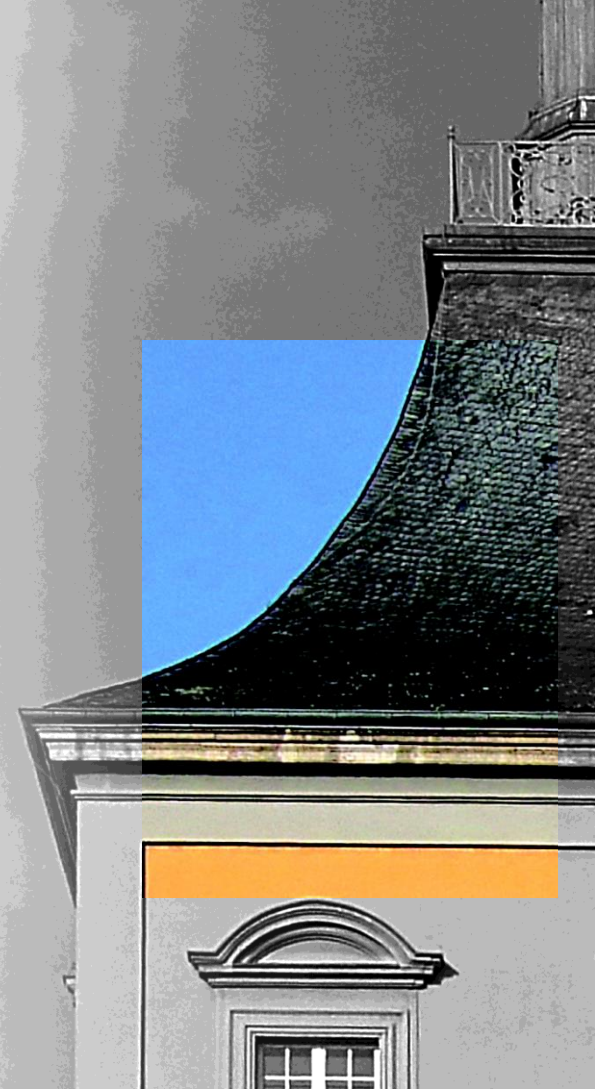
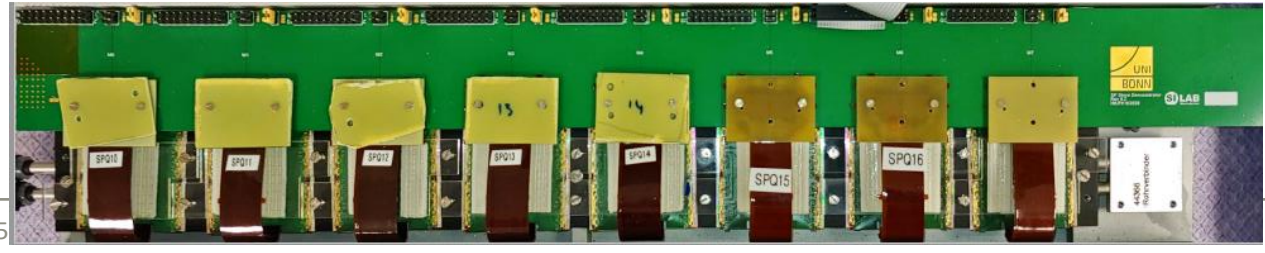
RD53A PLANAR SP CHAIN UPDATE

MATTHIAS HAMER, FLORIAN HINTERKEUSER



RD53A PLANAR SERIAL POWERING CHAIN – REVISED SERVICES

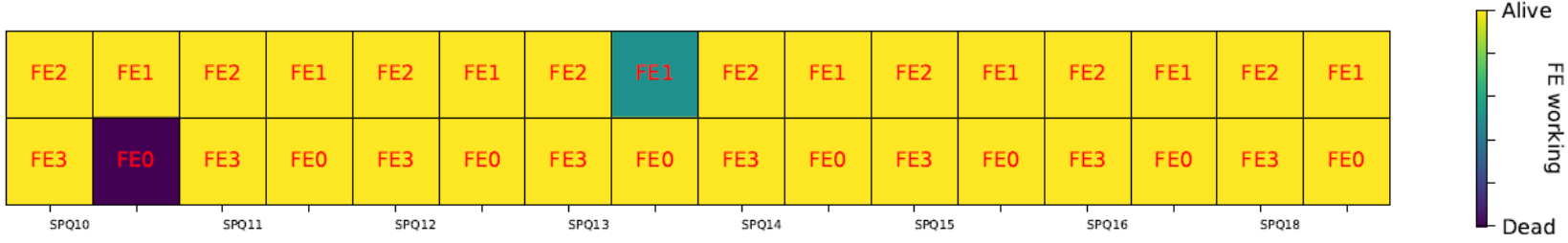
- Using new flexes, **first 10 modules** have been built (**1 digital, 9 thick quads**)
  - **Yield** from quick reception test **promising**: **7 thick quads fully working** (SPQ11-16, SPQ18)
  - **Completed** module characterisation (**SLDO IV, Sensor IV, FE-characterisation**) on all 10 quads
- **First 8 Quads loaded** on stave, „worst“ operational module SPQ17 left out
  - **SLDO IV curves** of all modules in serial chain measured
  - Measured **threshold distributions** & general chip functionality **for all FE** after tuning to **2ke** & **1ke** (LIN & DIFF only) & required startup current for all modules
  - Current headroom measurements currently ongoing



Quads SPQ10-SPQ16 & SPQ18 loaded on stave, connected to new revision of stave flex and EoS-Card (not shown).

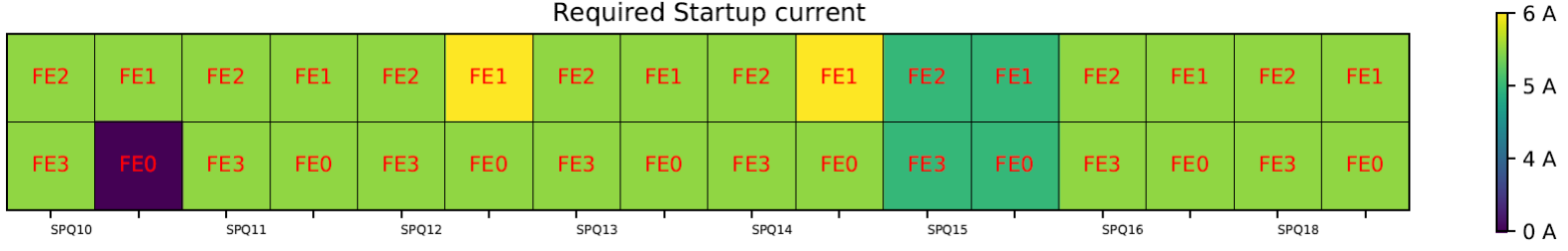
RD53A PLANAR SERIAL POWERING CHAIN – MODULE YIELD

- All chips on-stave but one are alive & communicating
  - SPQ10_FE0 has faulty SLDO, can‘t communicate
  - SPQ13_FE1 analog dead after tuning to 1ke



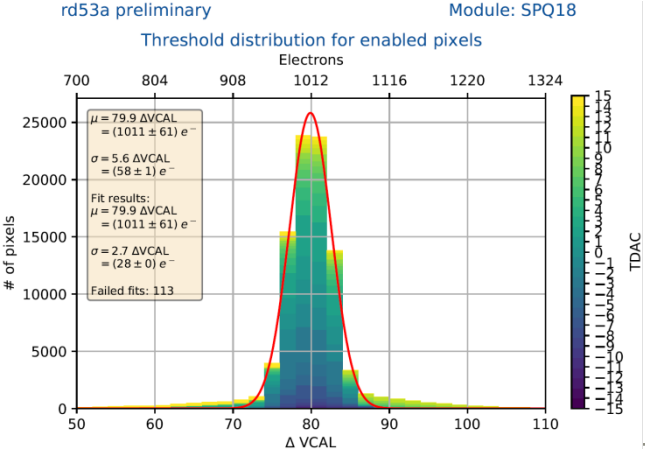
RD53A PLANAR SERIAL POWERING CHAIN – MODULE PERFORMANCE

- All chips on-stave but one are alive & communicating
- SPQ10_FE0 has faulty SLDO, can‘t communicate
- **Most** modules require $\mathbf{I_{In} \geq 5A}$ to fully start
  - First FE start around 3A
- **Some** require **up to 6A** for startup
- > **RD53A specific problem**

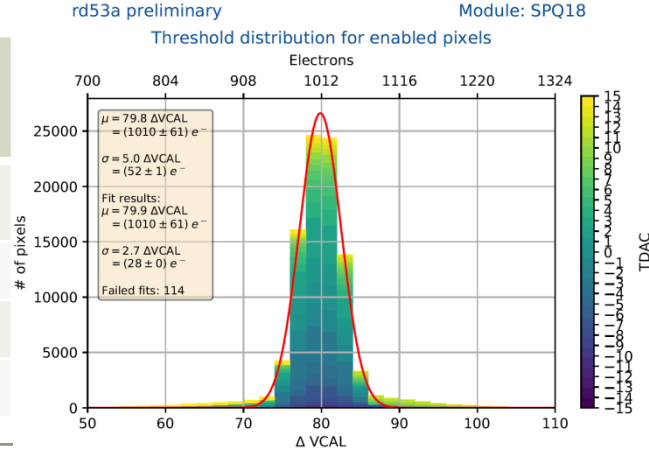


RD53A PLANAR SERIAL POWERING CHAIN – MODULE PERFORMANCE

- For all modules: tuning to 2ke / 1ke, measure threshold distr., noise, in-time-threshold in SP chain
  - Compare with results from module reception tests
  - Track for different HV schemes, chain current, chain length […]



SPQ18_DIFF	Stave, Solo	Stave, SP chain, 1 common HV_{In}, 1 HV_{ret}
Threshold	1011 e	1010 e
Thresh. Disp	28 e	28 e
Noise	(108 ± 7) e	(110 ± 7) e
Failed Fits	113	114



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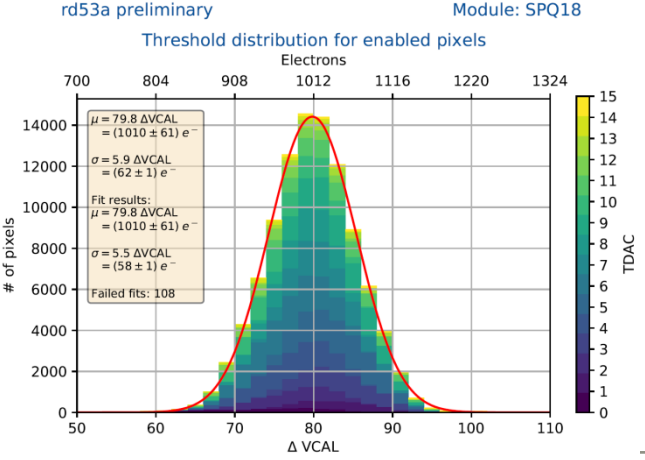
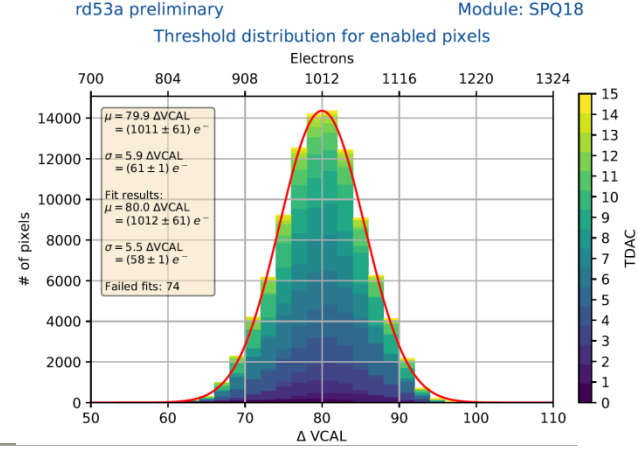


SPQ18_LIN	Stave, Solo	Stave, SP chain, 1 common HV_{In}, 1 HV_{ret}
Threshold	1010 e	1012 e
Thresh. Disp	58 e	58 e
Noise	(190 ± 10) e	(192 ± 10) e
Failed Fits	108	74



RD53A PLANAR SERIAL POWERING CHAIN – MODULE PERFORMANCE

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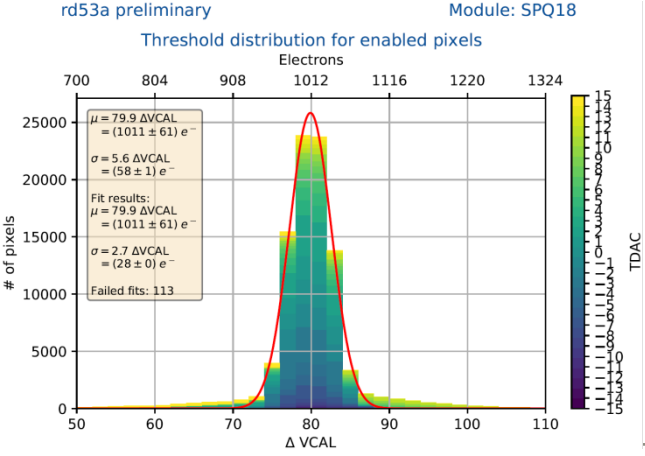
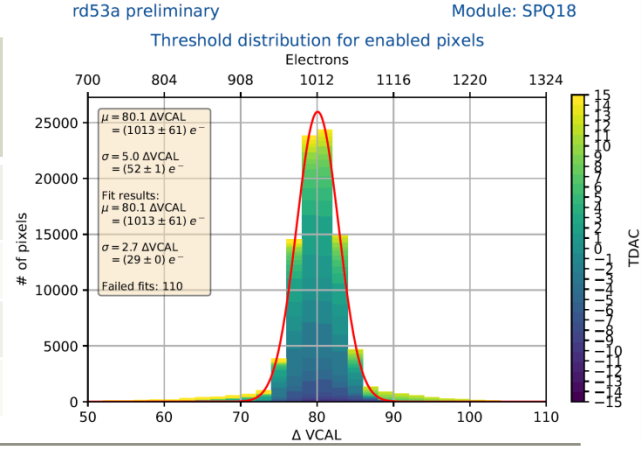


SPQ18_DIFF	Stave, Solo	Stave, SP chain, 2 common HV_{In}, 2 HV_{ret}
Threshold	1011 e	1013 e
Thresh. Disp	28 e	29 e
Noise	(108 ± 7) e	(109 ± 8) e
Failed Fits	113	110



RD53A PLANAR SERIAL POWERING CHAIN – MODULE PERFORMANCE

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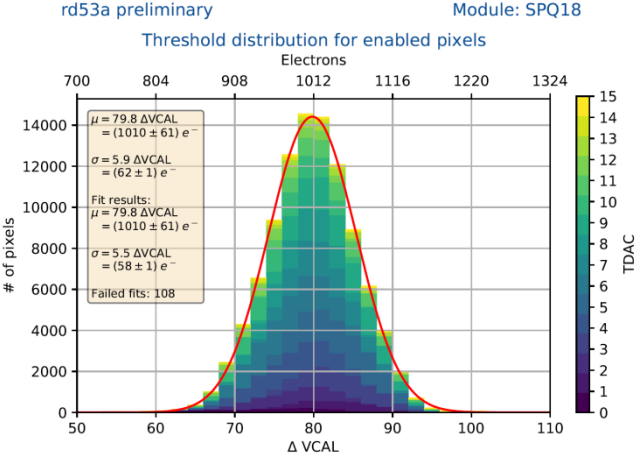
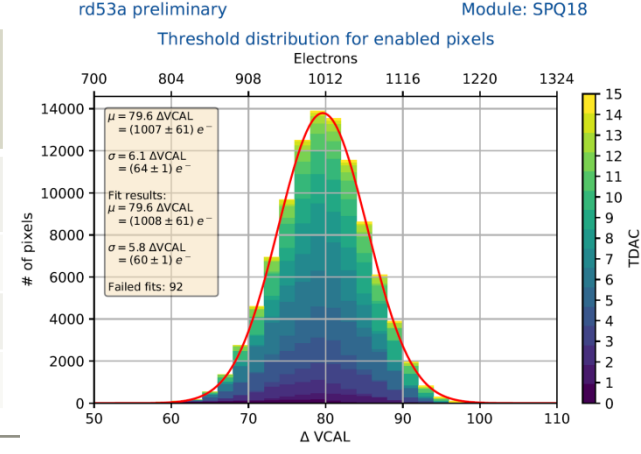


SPQ18_LIN	Stave, Solo	Stave, SP chain, 2 common HV_{In}, 2 HV_{ret}
Threshold	1010 e	1008 e
Thresh. Disp	58 e	60 e
Noise	(190 ± 10) e	(191 ± 10) e
Failed Fits	108	92



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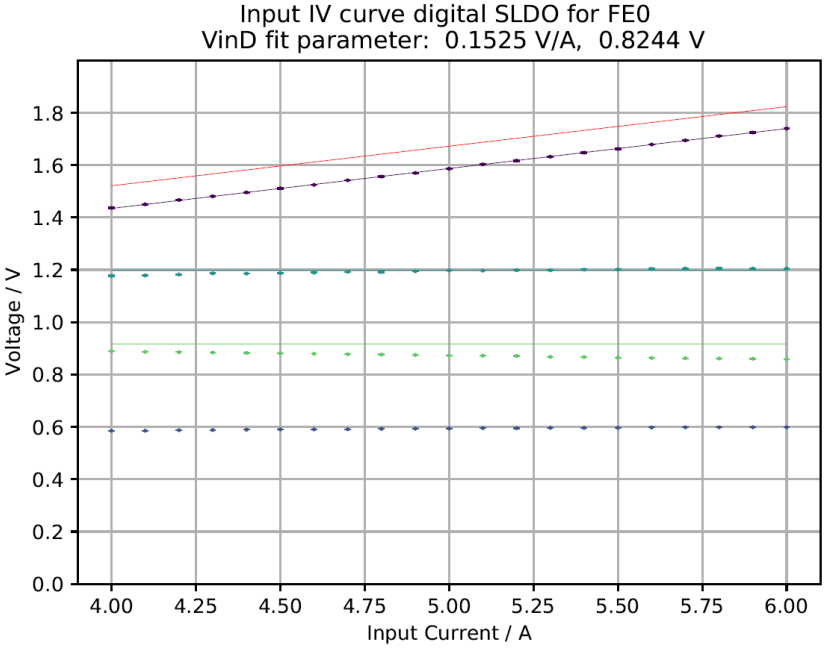
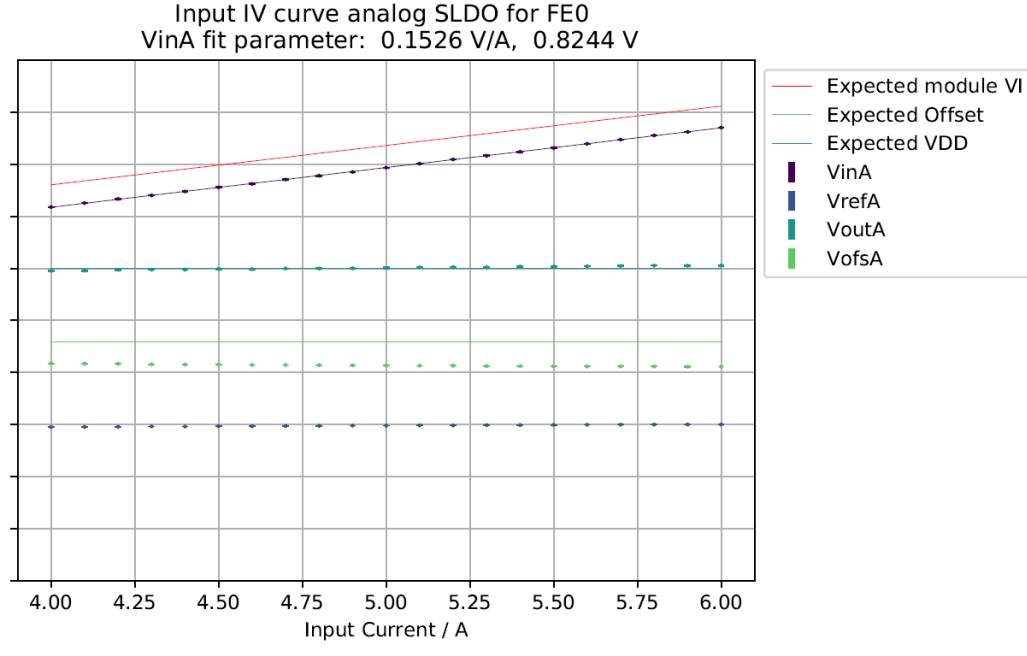
RD53A PLANAR SERIAL POWERING CHAIN – MODULE IV CURVES

- Measure **SLDO IV** curve for each quad in serial chain & compare with bench test / expectation
  - **From flex loading** expect: **V_{ofs} = 0.9 V, V_{in} ≈ 1.5 V @ Iin = 4.5 A, V_{DDD}=V_{DDA}= 1.2 V**
- **Measure** V_{in}, $V_{Out,}$ V_{ref}, V_{ofs} using **on-chip MUX** (corrected by GND offset)
  - In addition current through Rext for on-module current sharing
- Expectation: **constant** V_{ref}, V_{out}, V_{ofs}; Input **slope** from **spice**
  - using **Vofs, slopes** obtained in **wafer probing** when possible

RD53A PLANAR SERIAL POWERING CHAIN – MODULE IV CURVES





RD53A PLANAR SERIAL POWERING CHAIN – MODULE IV CURVES – PRELIMINARY SUMMARY

- Measured **SLDO IV** curve for each quad in serial chain
  - **$V_{IN\_A,D}$ tied** together on flex
  - > **Fits** on **V_{in}** in very good **agreement**
  - **Slope** fits expectation well
  - **Offset too small**
  - **> known to be RD53A specific**

SPQ13	Slope A	Offset A	Slope D	Offset D
FE0	0.1526 V/A	0.824 V	0.1525 V/A	0.8244 V
FE1	0.1524 V/A	0.828 V	0.153 V/A	0.826 V
FE2	0.1517 V/A	0.825 V	0.1511 V/A	0.828 V
FE3	0.153 V/A	0.825 V	0.1532 V/A	0.824 V

Spice	Full SPQ13
Slope	0.1512 V/A
Offset	0.916 V

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RD53A PLANAR SERIAL POWERING CHAIN – MODULE IV CURVES – PRELIMINARY SUMMARY

- **Tried to estimate** on-module **current distribution** using voltage drop on **slope resistors**
- Current mirror ratio ***k*** from **slope fit** on **waferprobing data**
  - **Not always** usable probing **data available**
  - **Does not include dependency** of *k* on **input current** (k increases with I_{in})
  - > **Both** will **improve** significantly for **RD53B**
- **Track** current distribution through input IV
- This current distribution is an **estimate** based from observations, **not a hard truth**

RD53A PLANAR SERIAL POWERING CHAIN – MODULE IV CURVES – PRELIMINARY SUMMARY

- **Tried to estimate** on-module **current distribution** using voltage drop on **slope resistors**
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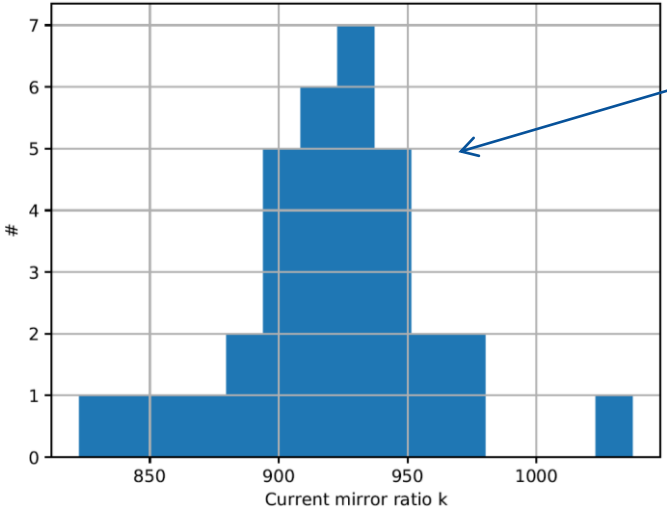
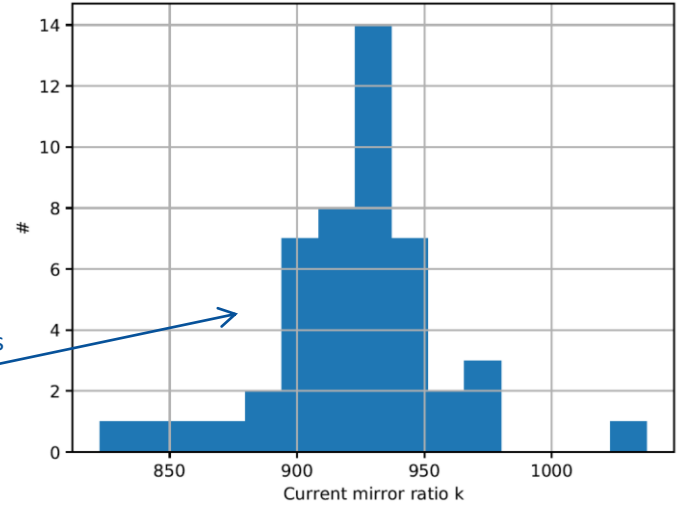


Current mirrors from available data (left), only good fits

Current mirrors with missing data replaced by average of remaining analog/digital SLDOs on given quad



RD53A PLANAR SERIAL POWERING CHAIN – MODULE IV CURVES – PRELIMINARY SUMMARY

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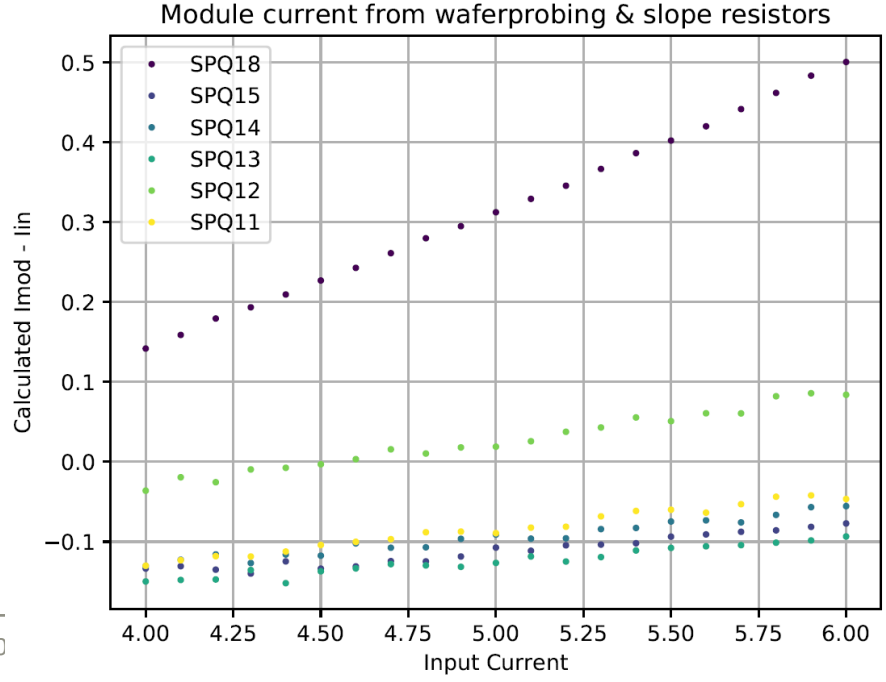
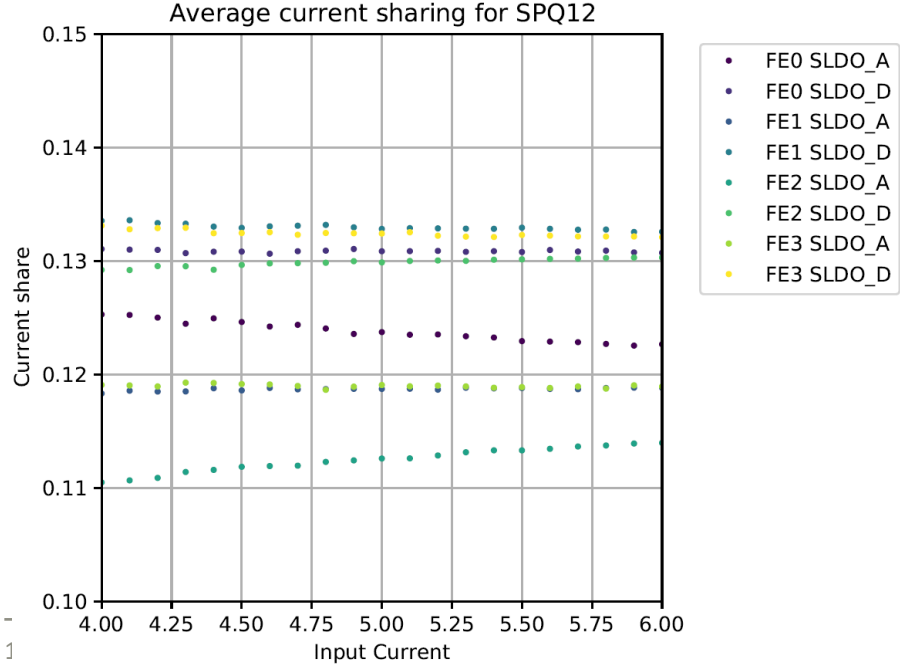


- **Estimate** module current I_{mod} by **scaling current** through **Rext** with current **mirror** from **wafer probing**
- Plot $\mathbf{I_{in}}$ vs $\mathbf{\Delta(I_{mod}, I_{in})}$
  - Significant uncertainties O(%)
  - Large slope on SPQ18 unexpected
- In general: slope on $\Delta(I_{mod}, I_{in})$ agrees with known slope on current mirror

RD53A PLANAR SERIAL POWERING CHAIN – MODULE IV CURVES – PRELIMINARY SUMMARY

- **Tried to estimate** on-module **current distribution** using voltage drop on **slope resistors**
- Current mirror ratio ***k*** from **slope fit** on **waferprobing data**



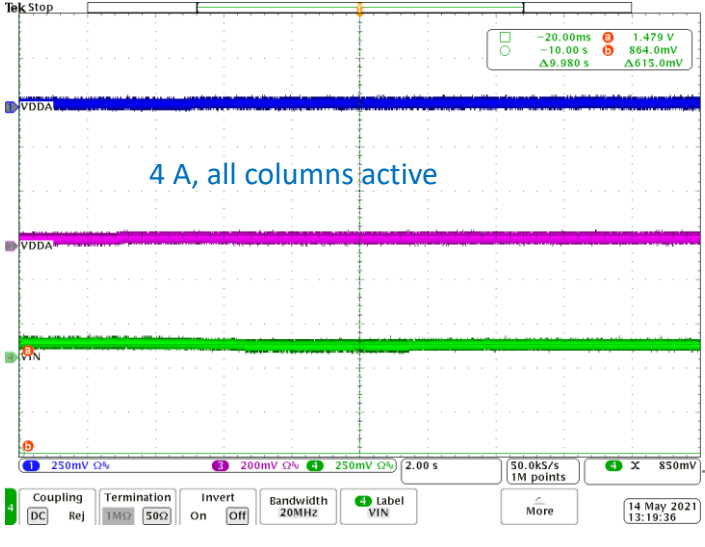
- **Estimate** module current I_{mod} by **scaling current** through **Rext** with current **mirror** from **wafer probing**
- Plot **relative current sharing** between SLDOs on a quad (**ideal case: 12.5 %**)
- Slope possibly explained by differing $k(I_{in})$ dependencies for each SLDO

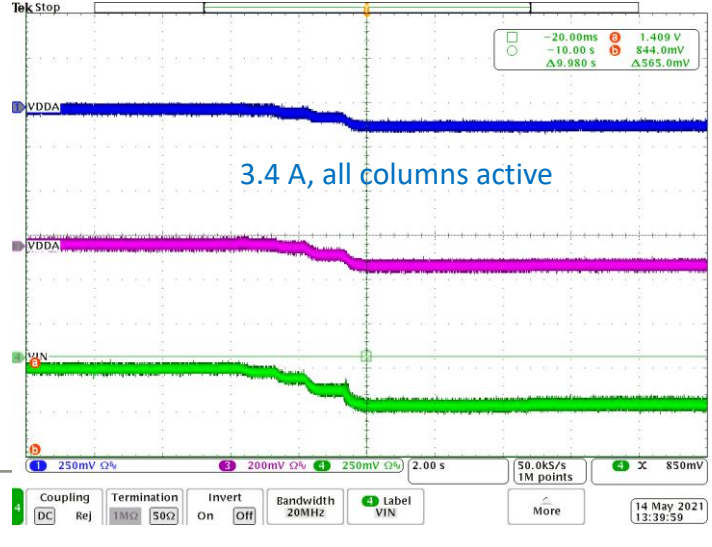
RD53A PLANAR SERIAL POWERING CHAIN – MODULE CURRENT HEADROOM

- Find **minimum** required **current** module to keep **module operational**
- **Baseline** for **SP Quads & common hybrid**: Module @ **1.5 V, 1.1 A / chip** (including headroom)
  -> ~ 4.4 A @ 1.5 V
- **Procedure**: Starting at a safe I_{in} (e.g. 6 A), run defined scan, reduce current, repeat
  - Scan used here: **„random“ trigger source scan** (w/o source), **all FE/flavours enabled**
  - **Track VDDAs / VIN_{Quad}** on scope
  - Significant **drop** in both **VIN & VDDA** -> SLDO **overload**

CURRENT HEADROOM

- Starting at I_{in} = 6A, **reducing in 100 mA** steps
  - **Once overload** is reached, measure **current** through **slope resistors**
  - **Decrease** module current **consumption** by **disabling** parts of the chip -> does overload go away?





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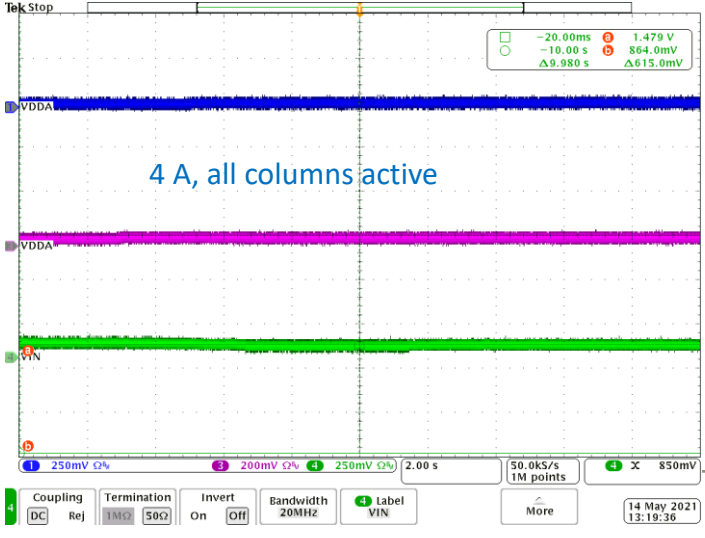

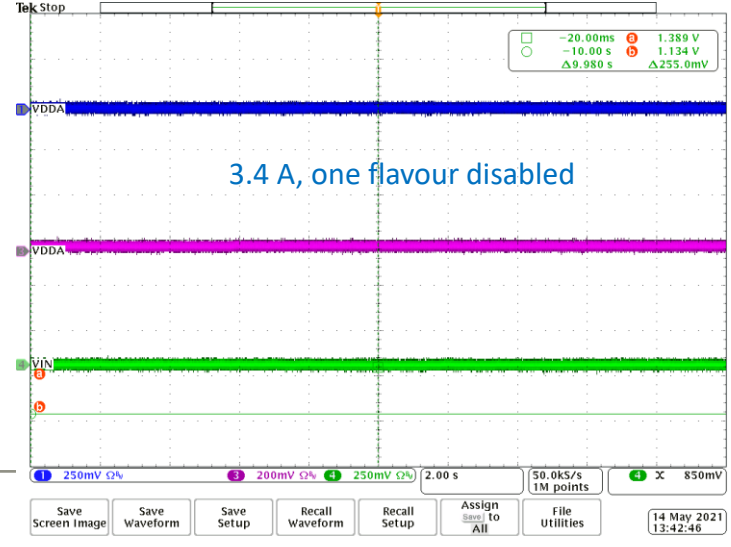

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CURRENT HEADROOM

- Starting at I_{in} = 6A, **reducing in 100 mA** steps
  - **Once overload** is reached, measure **current** through **slope resistors**
  - **Decrease** module current **consumption** by **disabling** parts of the chip -> does overload go away?

Quad	I_{in} overload / A	Module Voltage / V
SPQ11	3.8	1.4
SPQ12	3.4	1.34
SPQ13	3.6	1.37
SPQ14	3.4	1.35
SPQ15	3.5	1.36
SPQ18	3.5	1.37

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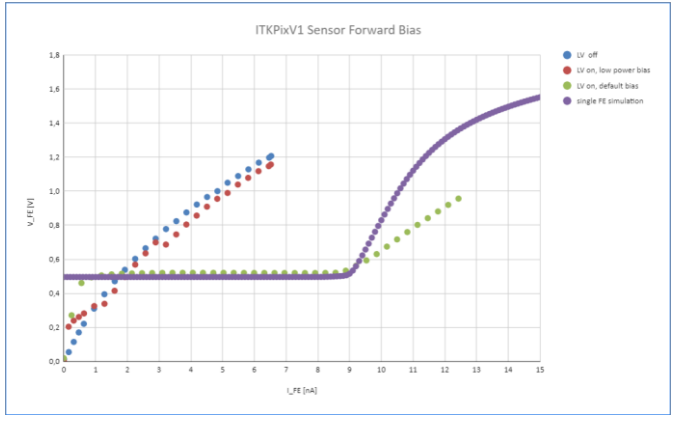
CURRENT HEADROOM

- Starting at I_{in} = 6A, **reducing in 100 mA** steps
  - **Once overload** is reached, measure **current** through **slope resistors**
  - **Decrease** module current **consumption** by **disabling** parts of the chip -> does overload go away?
- For modules with higher overload current but same IV characteristic, larger current imbalance is expected
- This can not be observed with the currently available data

HV OFF MODE

- open question for HV modules was the requirement of the low-ohmic off-mode, it was not clear that this is really required
  - high impedance off-mode leads to substantial forward bias on sensors in SP chain during interfills
  - measurements done by Anastasia et al. at CERN with irradiated modules have provided an indication for the level of that forward bias and the expected currents (see Anastasia's presentation) for more details
  - led to a discussion in the sensor group: no issue for sensors, but concerns were raised about risks to the analog FE
  - follow-up measurements done in Bonn (H. Krüger et al.) with an unirradiated ITkPixV1 Chip bonded to a planar Micron sensor:



  - forward bias applied directly to the backside of the sensor through series resistor
  - voltage is measured at the bias grid (PT biasing for the used sensor)
  - worst case in the detector: < 3.5 nA per pixel
    - we don't expect to ever get there
    - Anastasia's measurements indicate a maximum current below that
  - results still require some more understanding:
    - behaviour of bias-grid potential for small currents (I-V of PT grid?)
    - difference between simulation and measurement at large currents (averaging effect?)
  - plan to repeat this measurement with the RD53A quad chain

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SUMMARY & OUTLOOK

- Characterisation of the **Bonn serial powering test setup** is progressing
  - **Results so far look promising**
  - Did not encounter any surprises
- Can **plug in digital ITkPix modules** when available
  - **First** ITkPix V1.0 **SP quad** wirebonded yesterday, currently **being tested**
  - **Expect** ITkPix V1.1 chips for digital SP quads to **arrive this week**
  - **Stave** loaded with **ITkPix** SP quads ~ **June**
  - **Setup with ITkPixV1.1** modules to be **shipped to CERN** for system tests with representative **long services**

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THANK YOU

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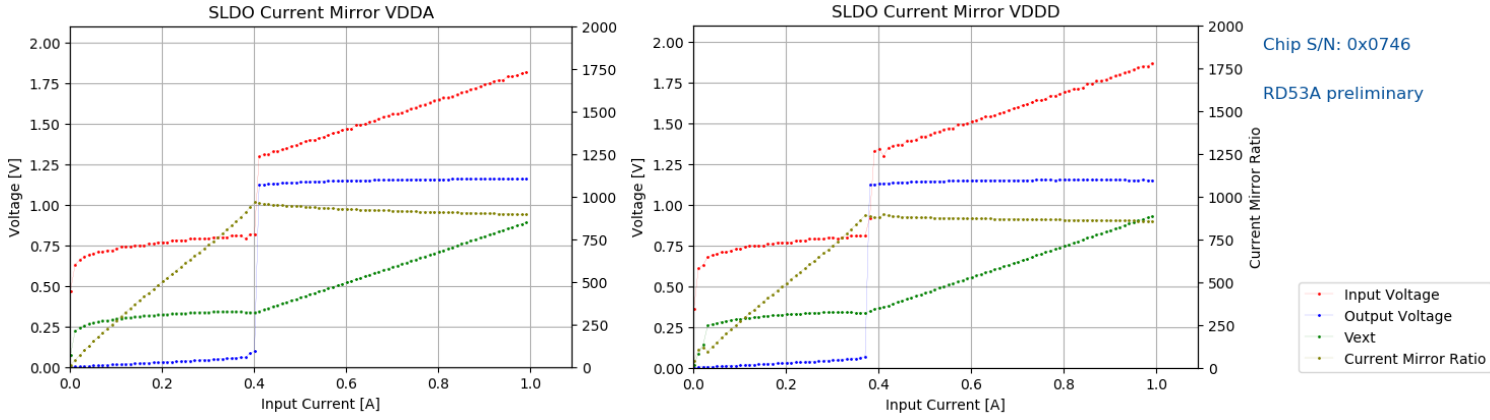
BACKUP

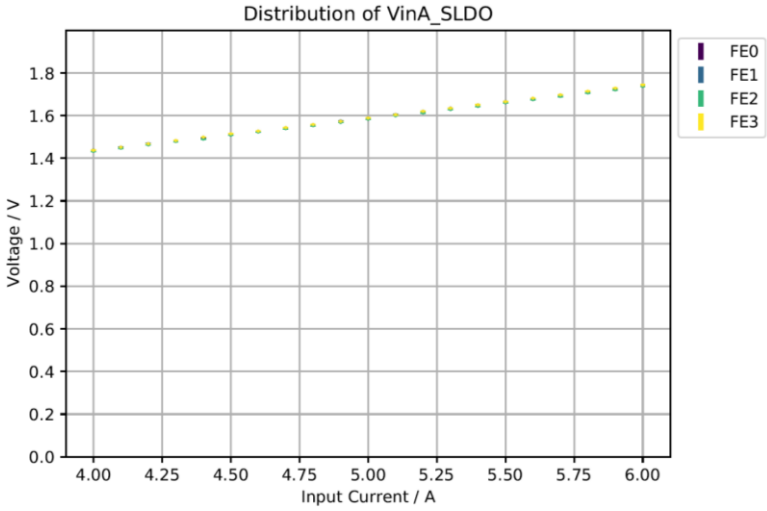
RD53A CURRENT MIRROR EXAMPLE

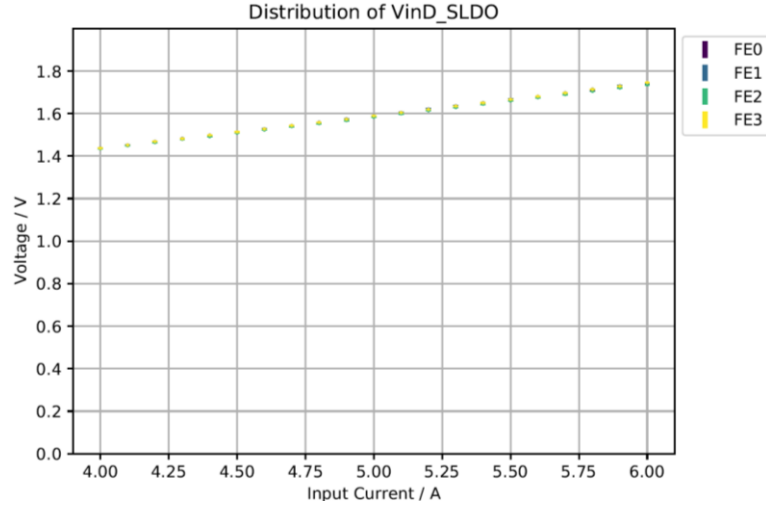
	Current Mirror
R_{ext}_A	895≤k≤965
R_{eff}_A	889
R_{ext}_D	857≤k≤894
R_{eff}_D	900
Ideal case	1000



- Current mirror ratio smaller than expected
  - K depends on input current
  - R_{eff} gives only estimate on k

VINA / VIND DISTRIBUTION ON SPQ13





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CURRENT HEADROOM

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SPQ14	3.4	1.35
SPQ15	3.5	1.36
SPQ18	3.5	1.37

SPQ18	$I_{SLDO,Analog}$ / A	$I_{SLDO,Digital}$ / A
FE0	0.42	0.4
FE1	0.455	0.46
FE2	0.448	0.415
FE3	0.4	0.45
Total	3.44 A	Expected 3.5 A

SPQ11	$I_{SLDO,Analog}$ / A	$I_{SLDO,Digital}$ / A
FE0	0.442	0.441
FE1	0.43	0.439
FE2	0.363	0.45
FE3	0.42	0.411
Total	3.4 A	Expected 3.8 A