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Combined Measurement Results of dedicated RD50 Charge Multiplication Sensors

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- Investigated Sensors
- Measurement Setup
- Comparison Setup Freiburg <-> Liverpool
- Charge Collection Measurements
- Conclusion



- At high fluences and bias voltages, charge multiplication of the signal in the detector has been observed
- Multiplication due to impact ionisation
 - Begins when electric field reaches 10-15 V/ μm
- Charge multiplication can be beneficial for sensors, leading to higher signal
 - Particular for not fully depleted sensors after high irradiation doses



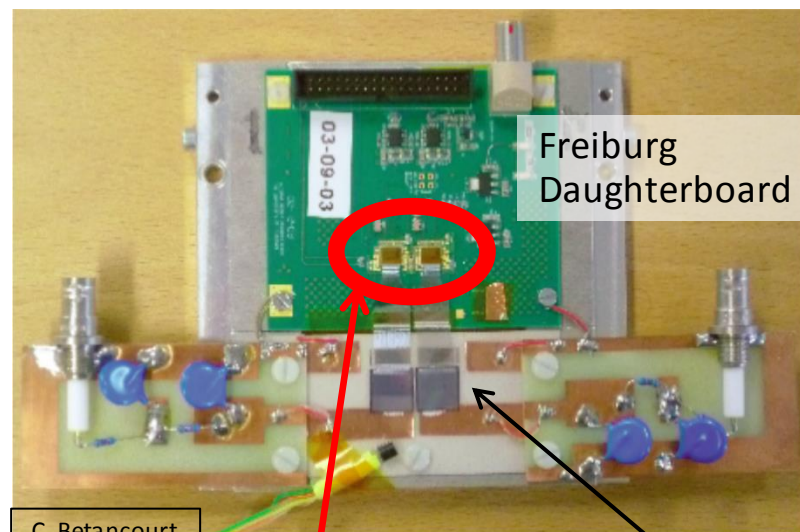
- Dedicated charge multiplication sensors, produced by MICRON
- 1cm x 1cm, n-in-p FZ strip detectors
- Various strip pitch (P) and width (W)
- Some sensors with floating (F) or biased (I) intermediate strips between readout strips

Serial No	Thickness [μm]	Resistivity [kΩ/cm]	Implant Details	Labelling
2912-(2,3)	300	10-13	Standard, double implant energy	2E imp
2935-10	305	13	Standard, double diffusion time	extra diff
2935-(2,4,5,6,7,8,9)	305	13	Standard	std
2488-(6,7)	675	8	Thick	thick
2885-5	150	10	Thin	thin

ALiBaVa Setup

Use ALiBaVa system for charge collection measurements

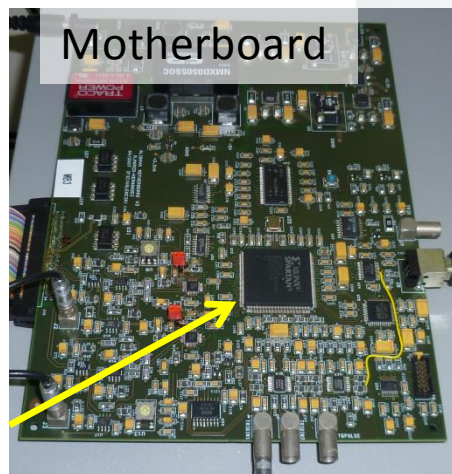
- Up to 2 sensors are attached to Beetle chips (ASIC) on the daughterboard for analogue readout (signal amplification and shaping)
- Daughterboard connected to motherboard, controlled by an FPGA (signal conversion into digital counts using a 10-bit Analogue to Digital Converter)
- Raw data sent to PC via USB cable and analysed by custom software based off the ROOT framework



C. Betancourt
21st RD50
Workshop

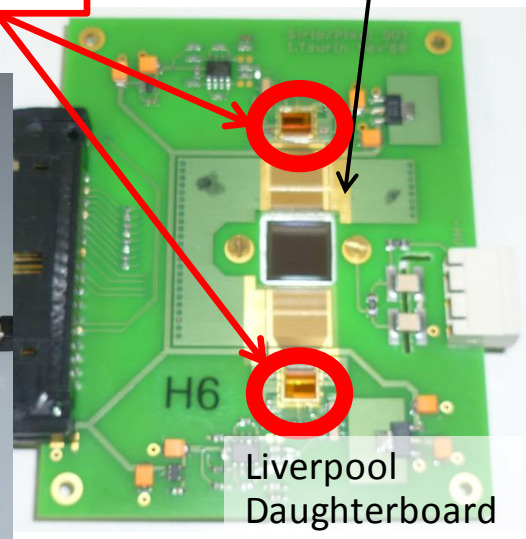
Beetle
Chip

Sensor



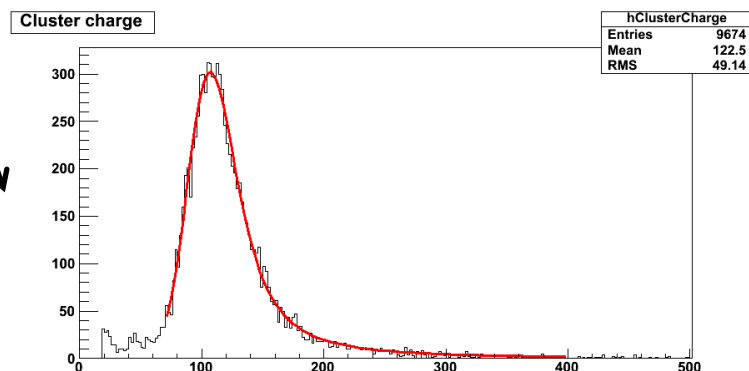
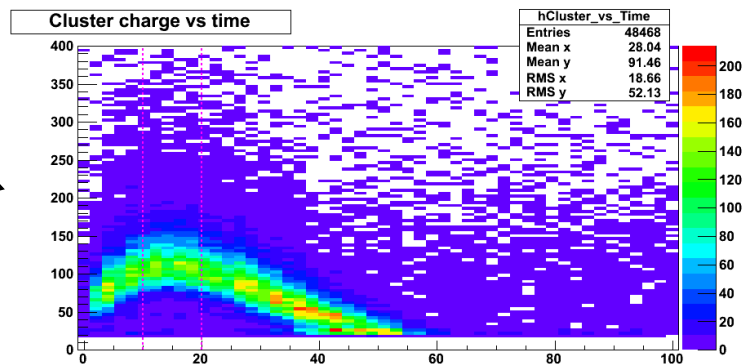
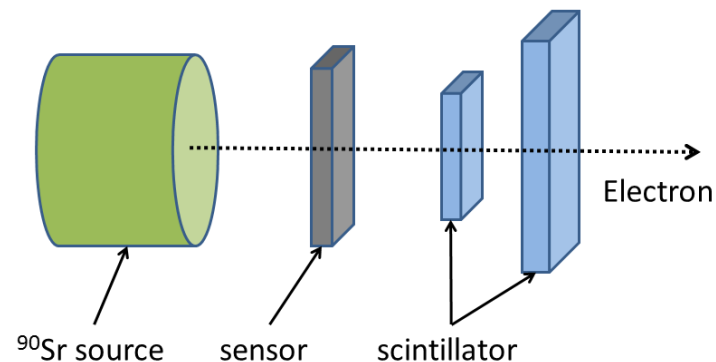
Motherboard

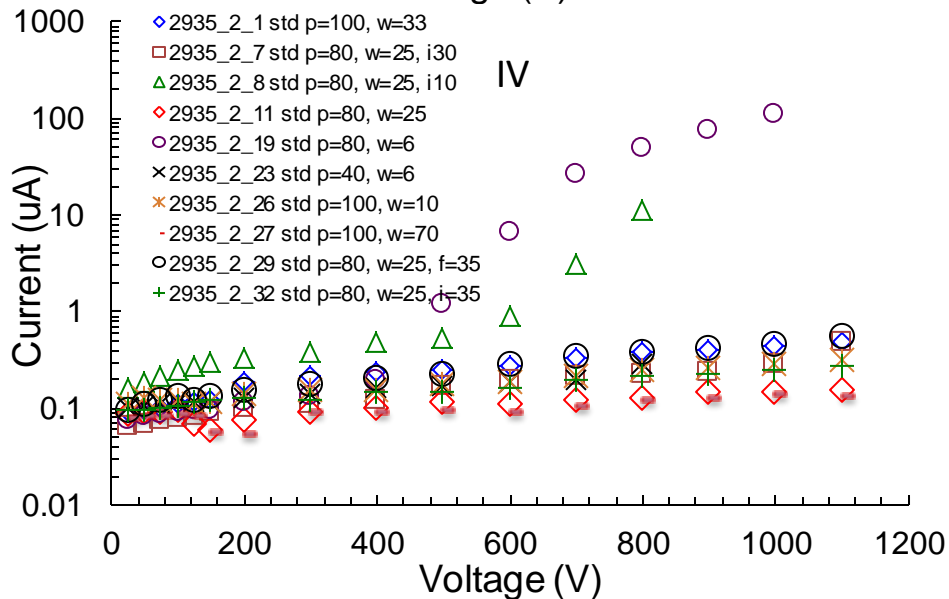
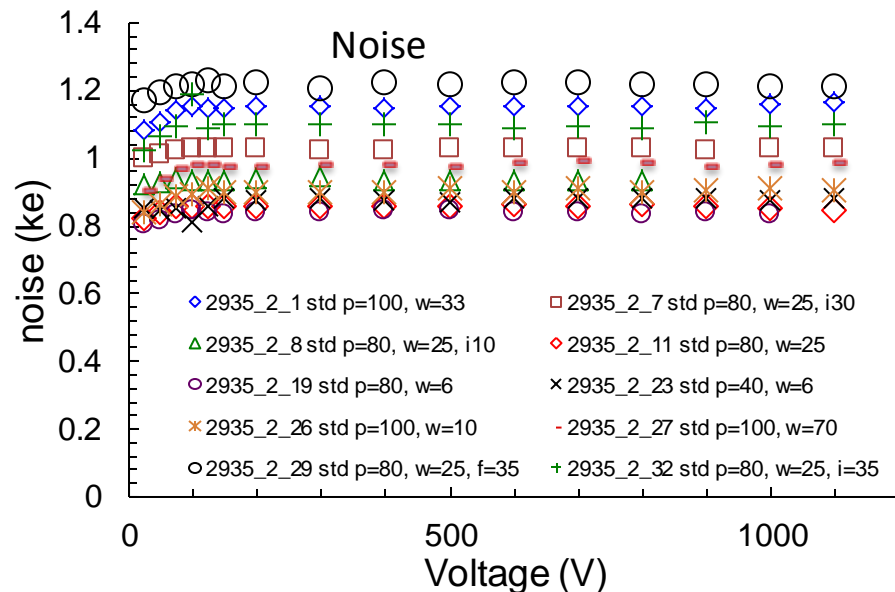
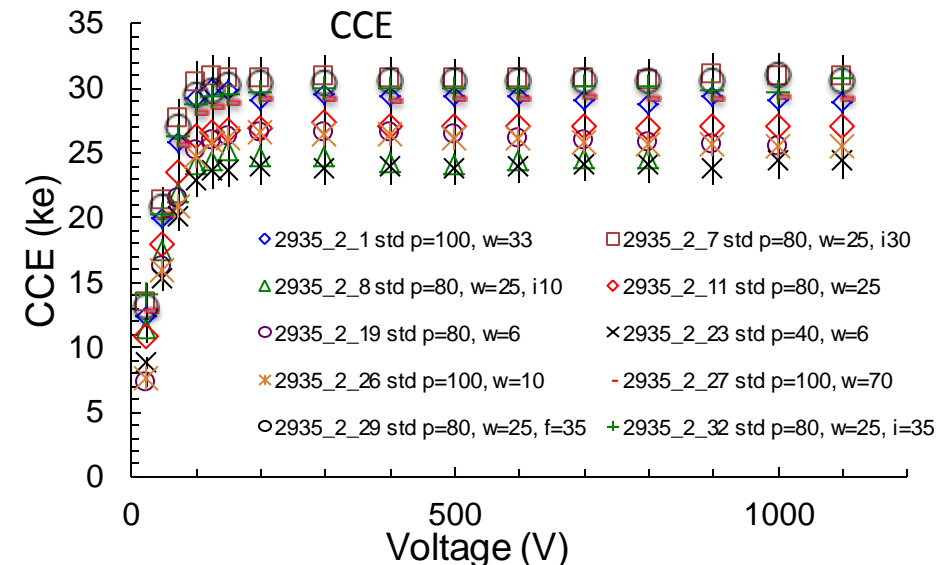
FPGA



Liverpool
Daughterboard

- MIP's from ^{90}Sr source to perform charge collection measurements
- Scintillators for triggering
- Time between trigger signal and edge of a 10MHz clock is measured by ALiBaVa TDC
- For each event, channel with largest SNR is chosen and mean is calculated for each 1 ns time bin
- Only events in 10ns window around maximum are considered
- Resulting spectrum is fitted with a convolution of a Gaussian and Landau distribution to determine MPV
- With calibration value of daughterboard the collected charge is calculated from the MPV





- Full depletion reached at 100-125V
- No charge multiplication observed up to 1100V
- Most sensors show no breakdown up to 1100V
- Large spread of collected charge -> see C. Betancourt, 21st RD50 Workshop



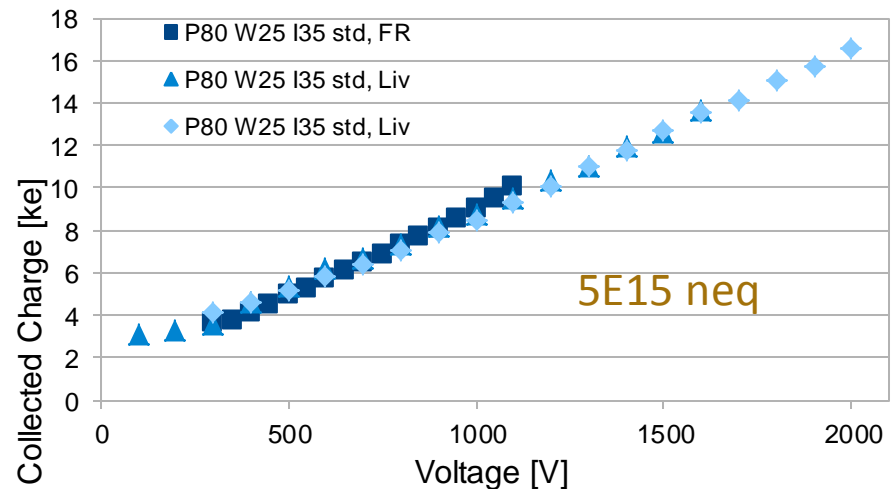
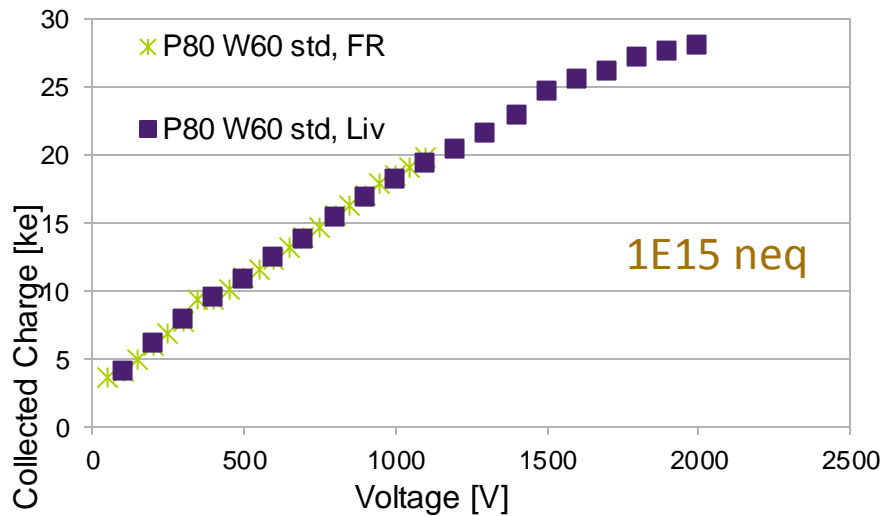
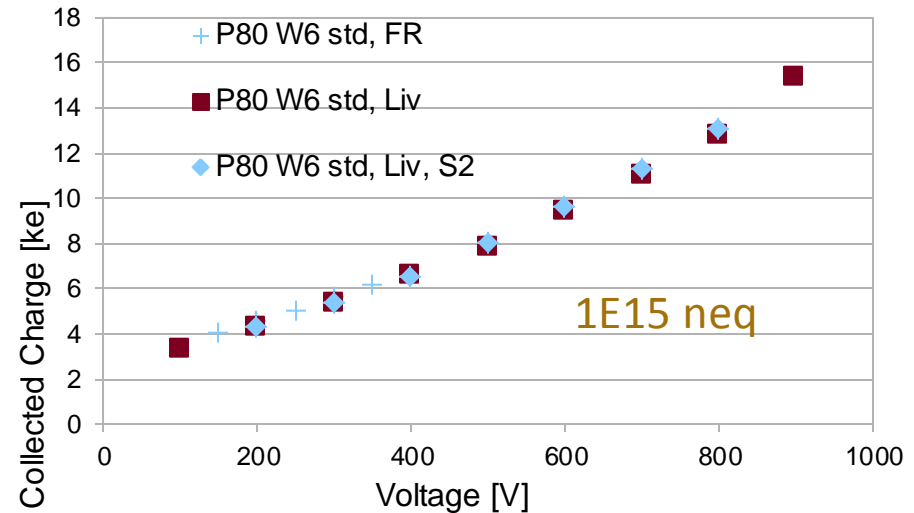
- Sensors with different geometries irradiated
 - 1×10^{15} 1MeV neq/cm² with Neutrons
 - 5×10^{15} 1MeV neq/cm² with Neutrons

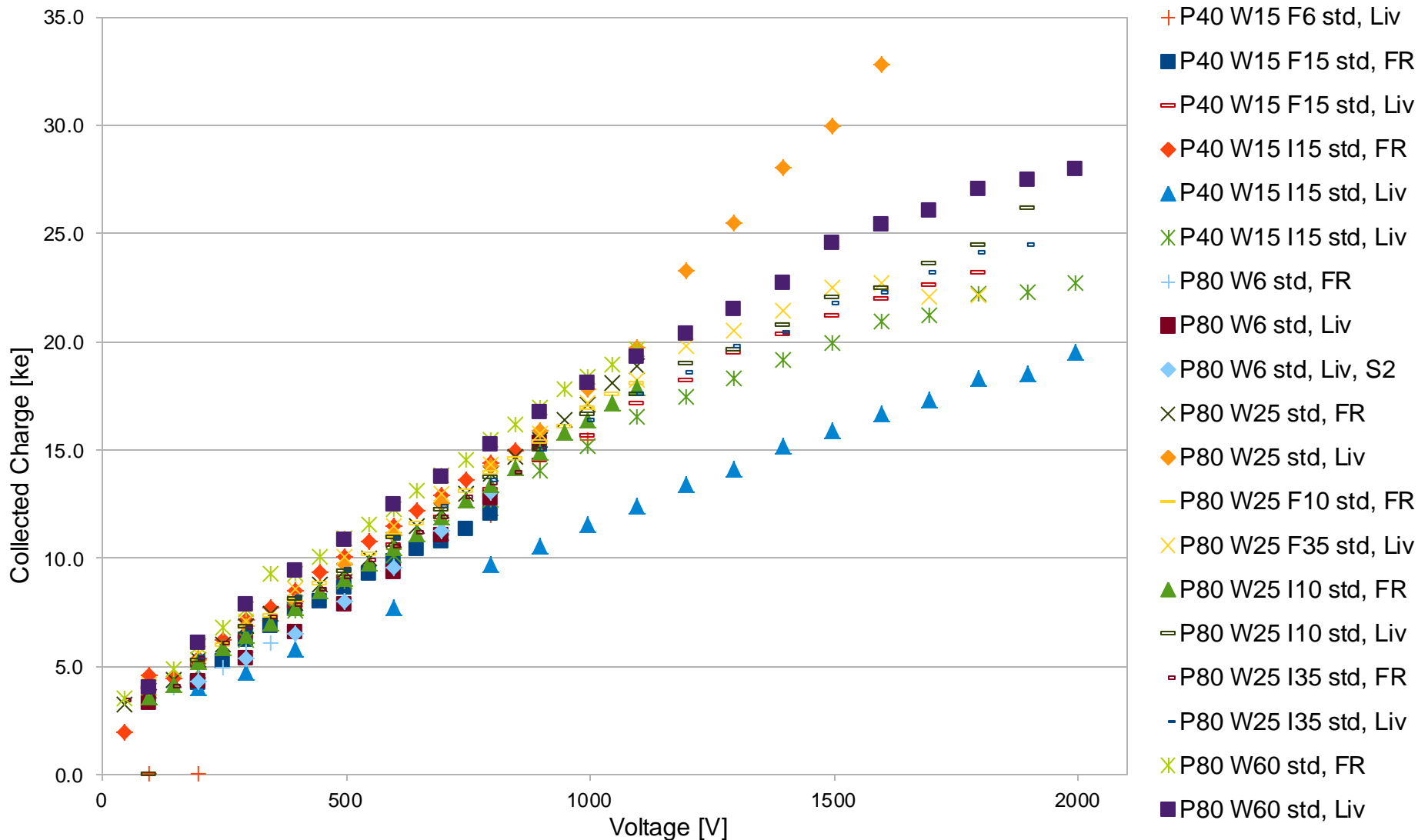
 - 1×10^{15} 1MeV neq/cm² with Protons
 - Sensors only available at Freiburg
 - Results shown by C. Betancourt at 21st RD50 Workshop

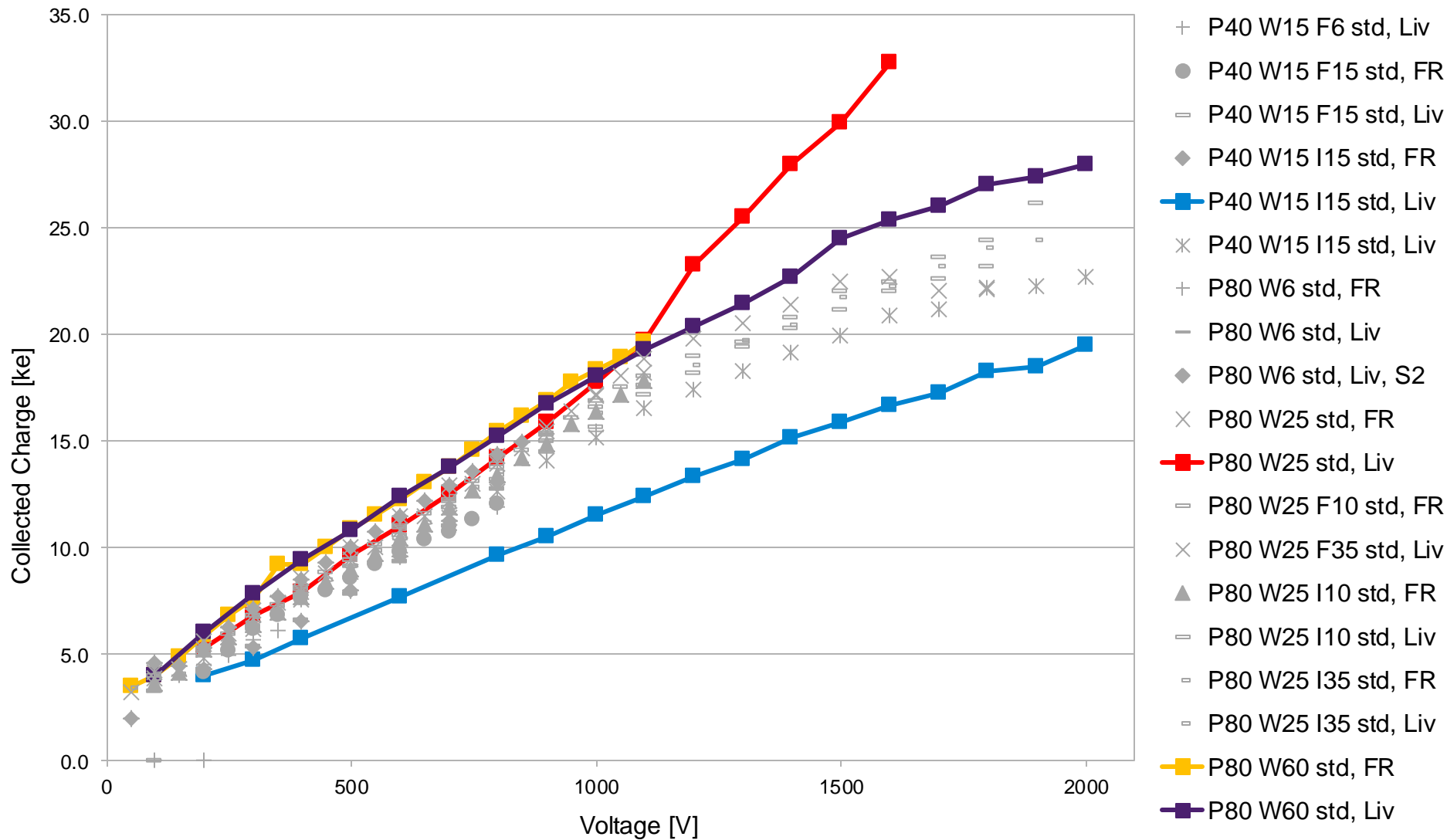


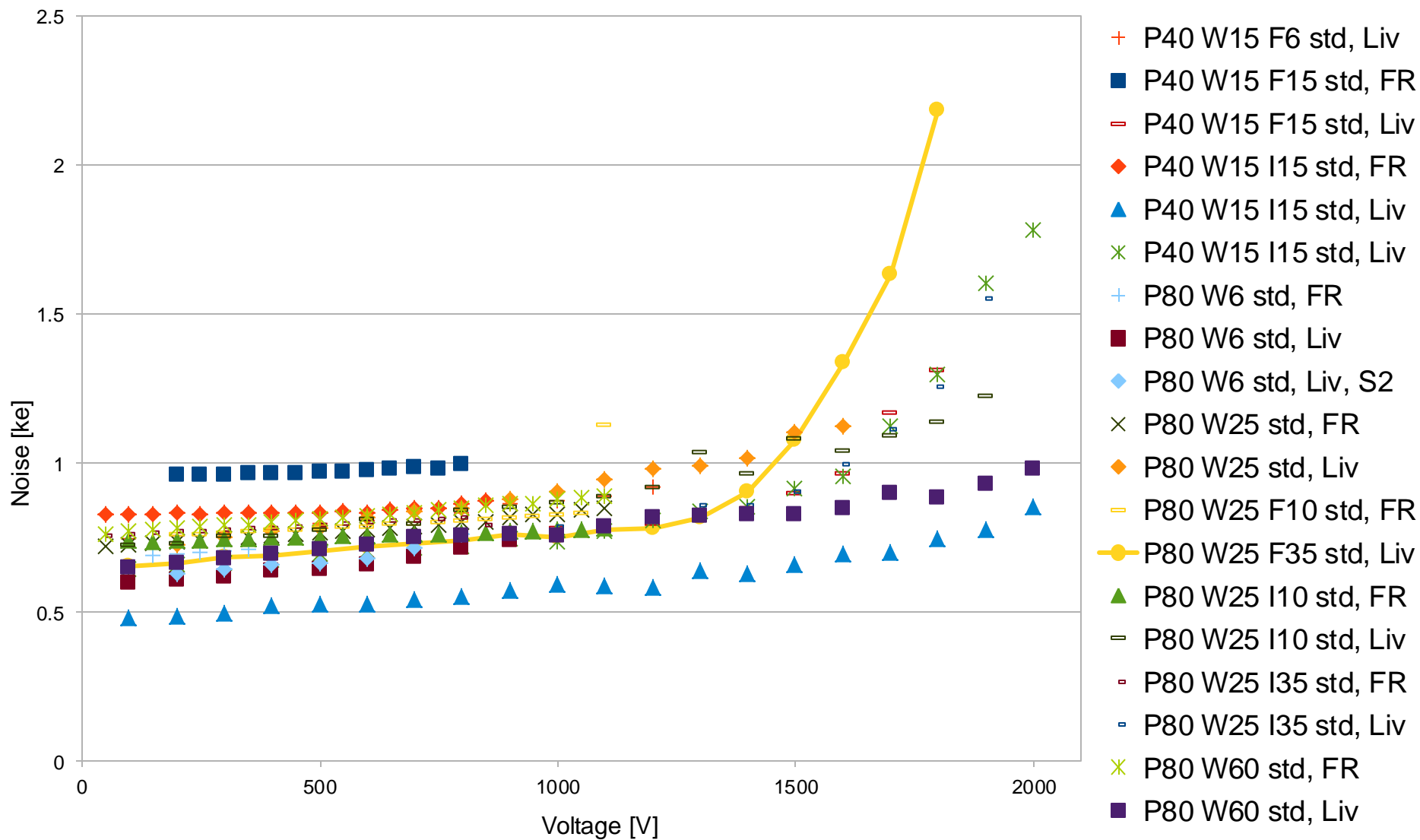
Comparability

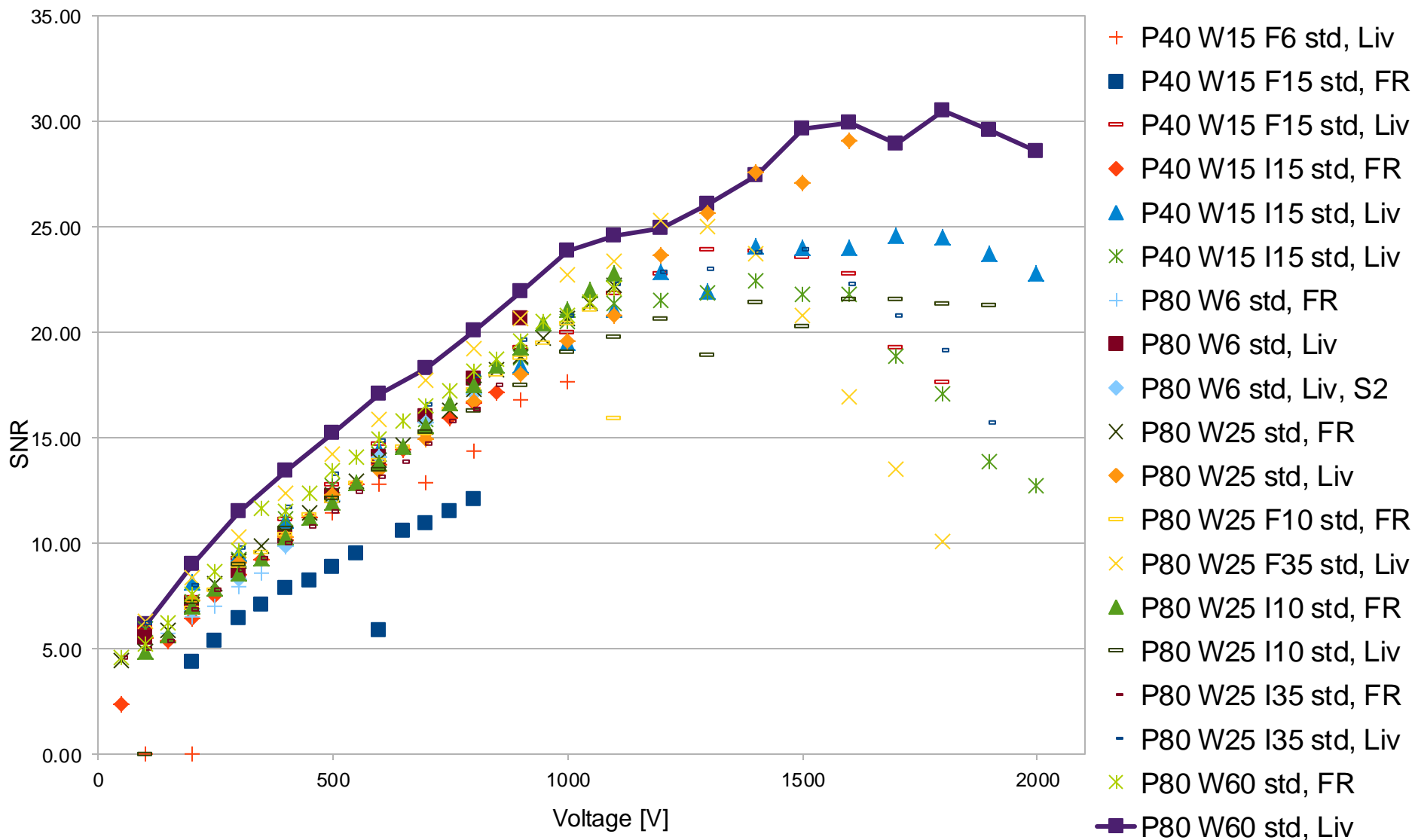
- Compare results of same sensor geometry and type
- Freiburg and Liverpool show same values
=> All measurements comparable











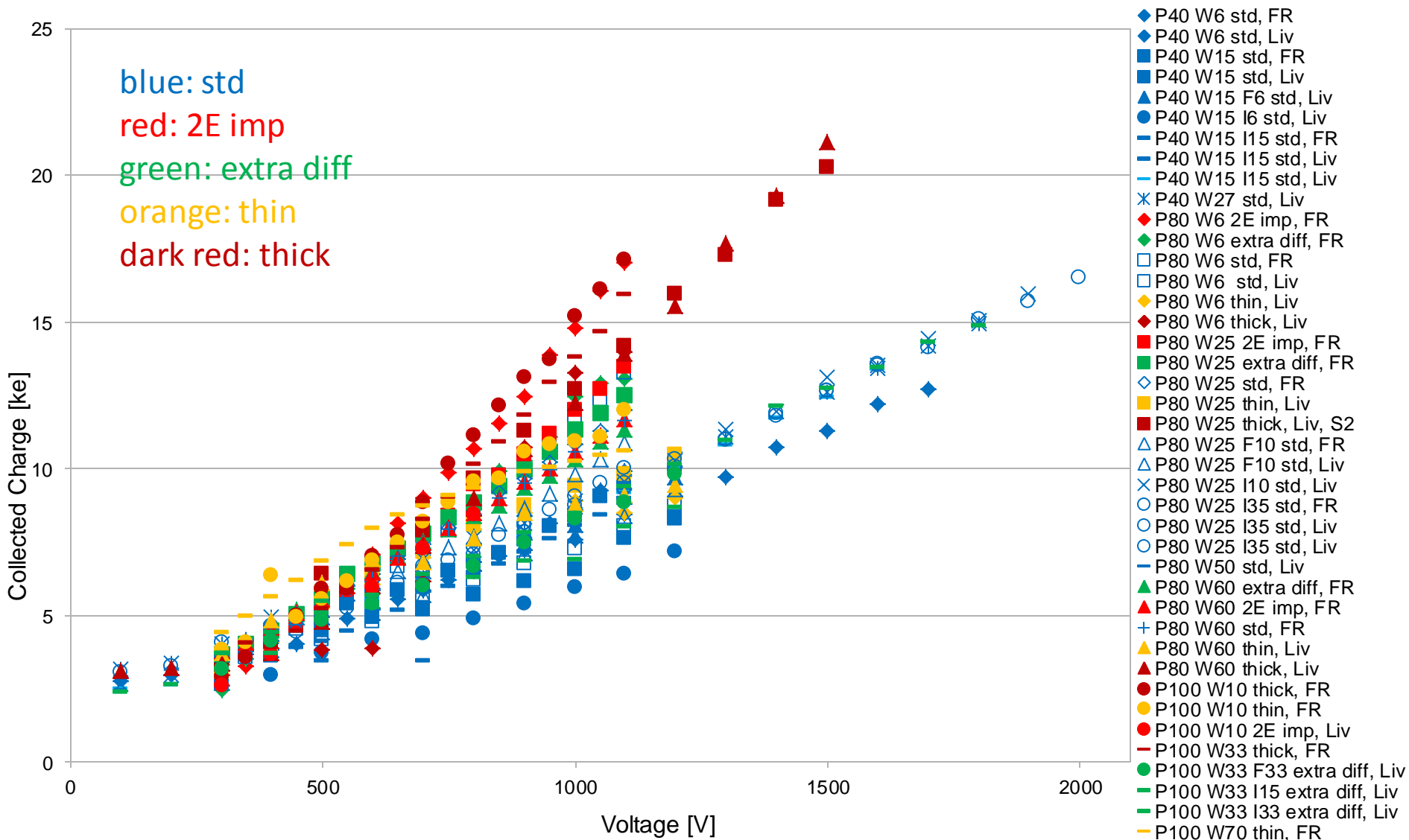


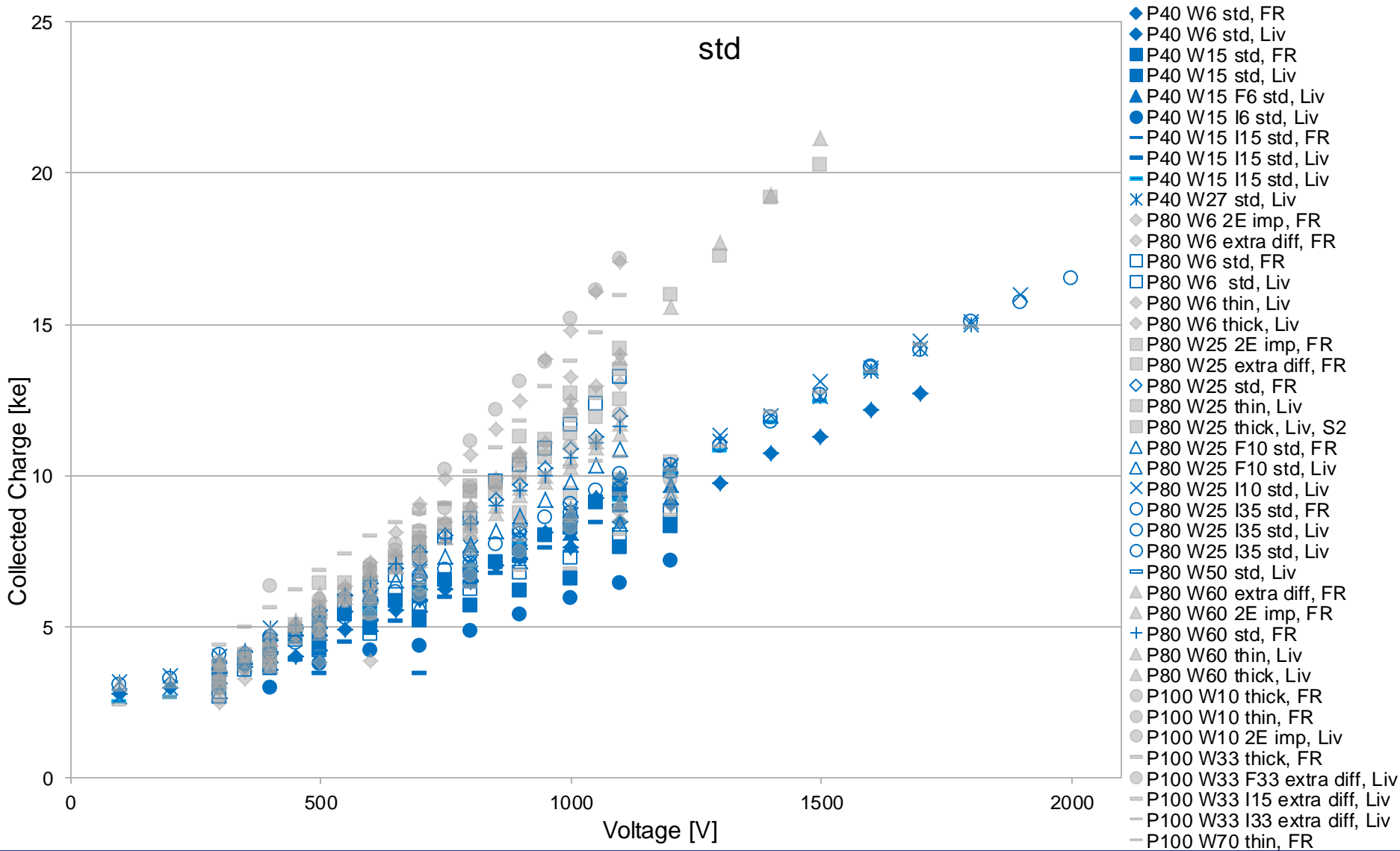
- Most sensors show same behaviour up to 800V
- P80 W25 (Liverpool measurement) show clear sign of charge multiplication above 1200V
- 'P40 W25 I15 std, Liv' show less collected charge, not consistent with measurement of other sensors of the same type
- 'P80 W60 std, Liv' show more collected charge than expected above 1500V

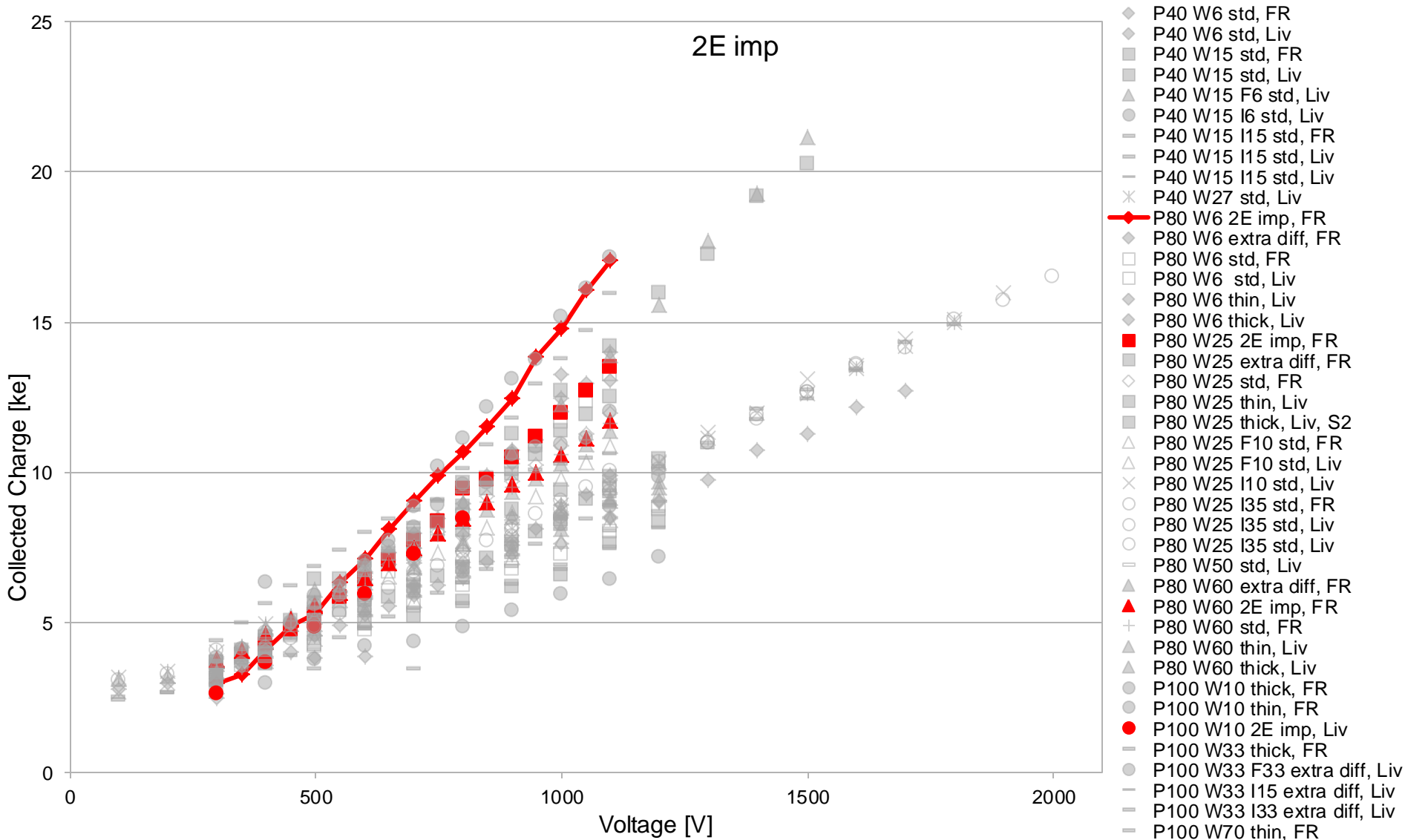
- Noise below 1ke up to 1400V, then slightly increasing
- P80 W25 F35 show very high noise, no second sensor with same geometry available to proof result

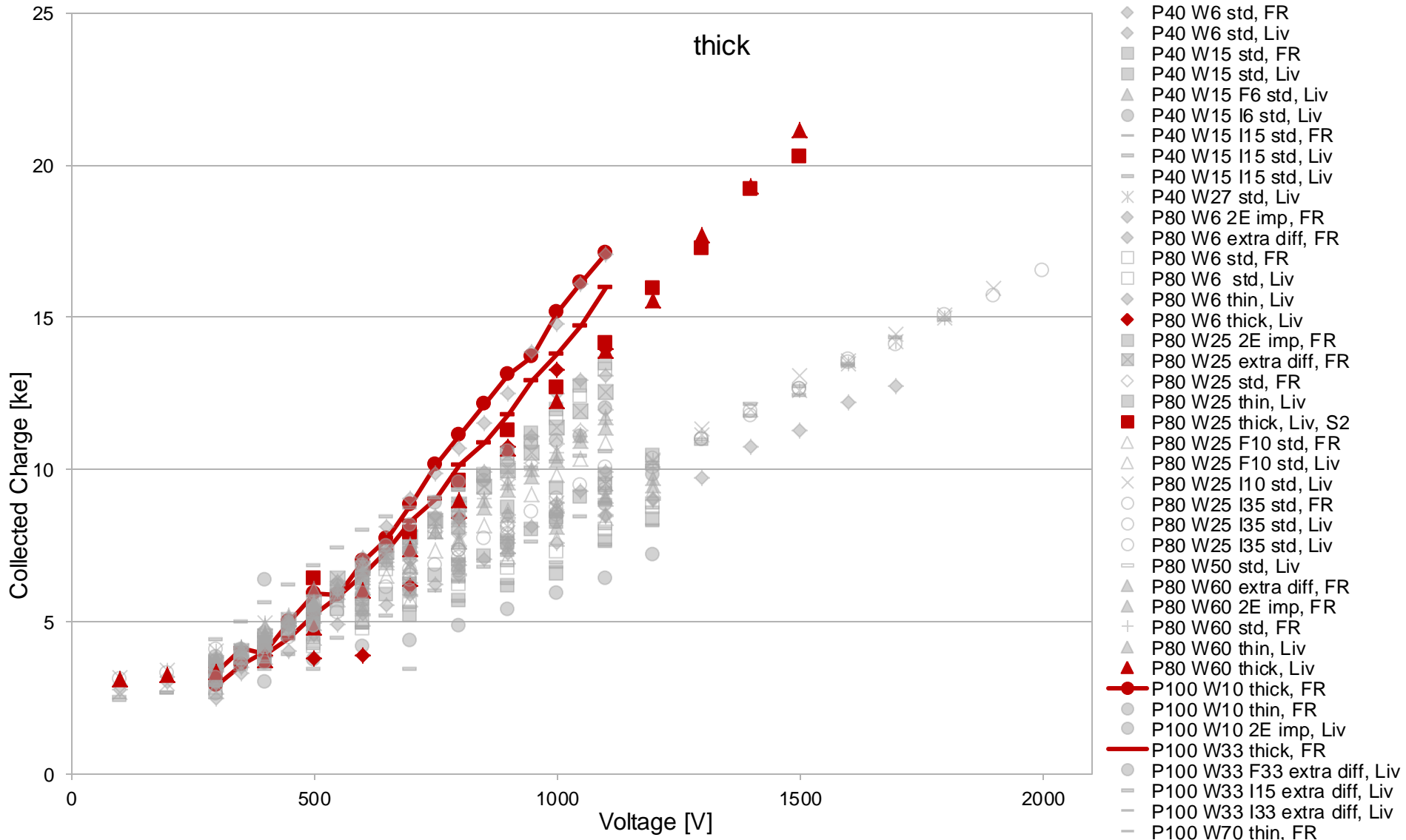
- SNR increase up to 1200V, then slightly decreasing
- Maximum SNR \approx 30 for P80 W60

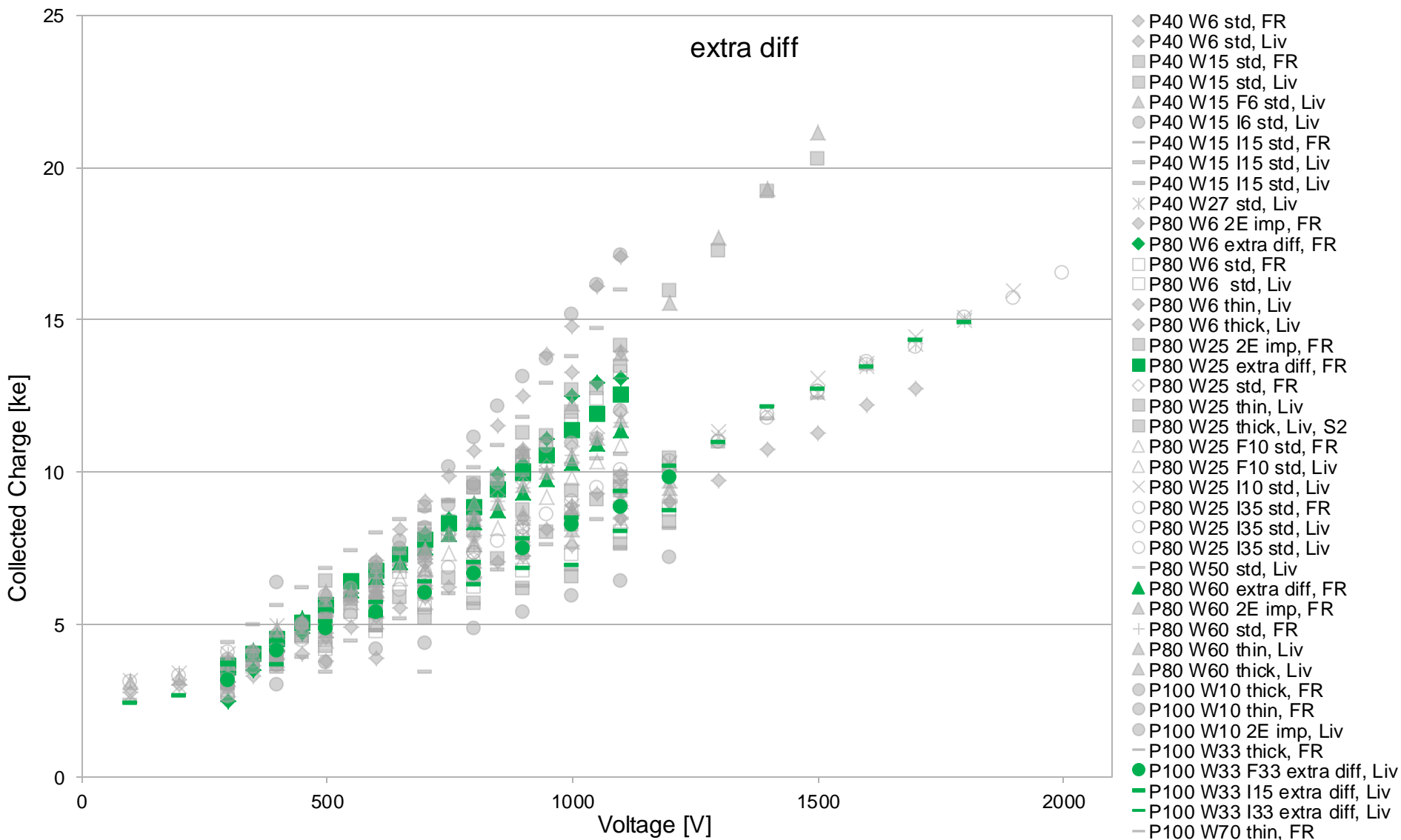
- **P80 W60 is a very promising candidate for charge multiplication**

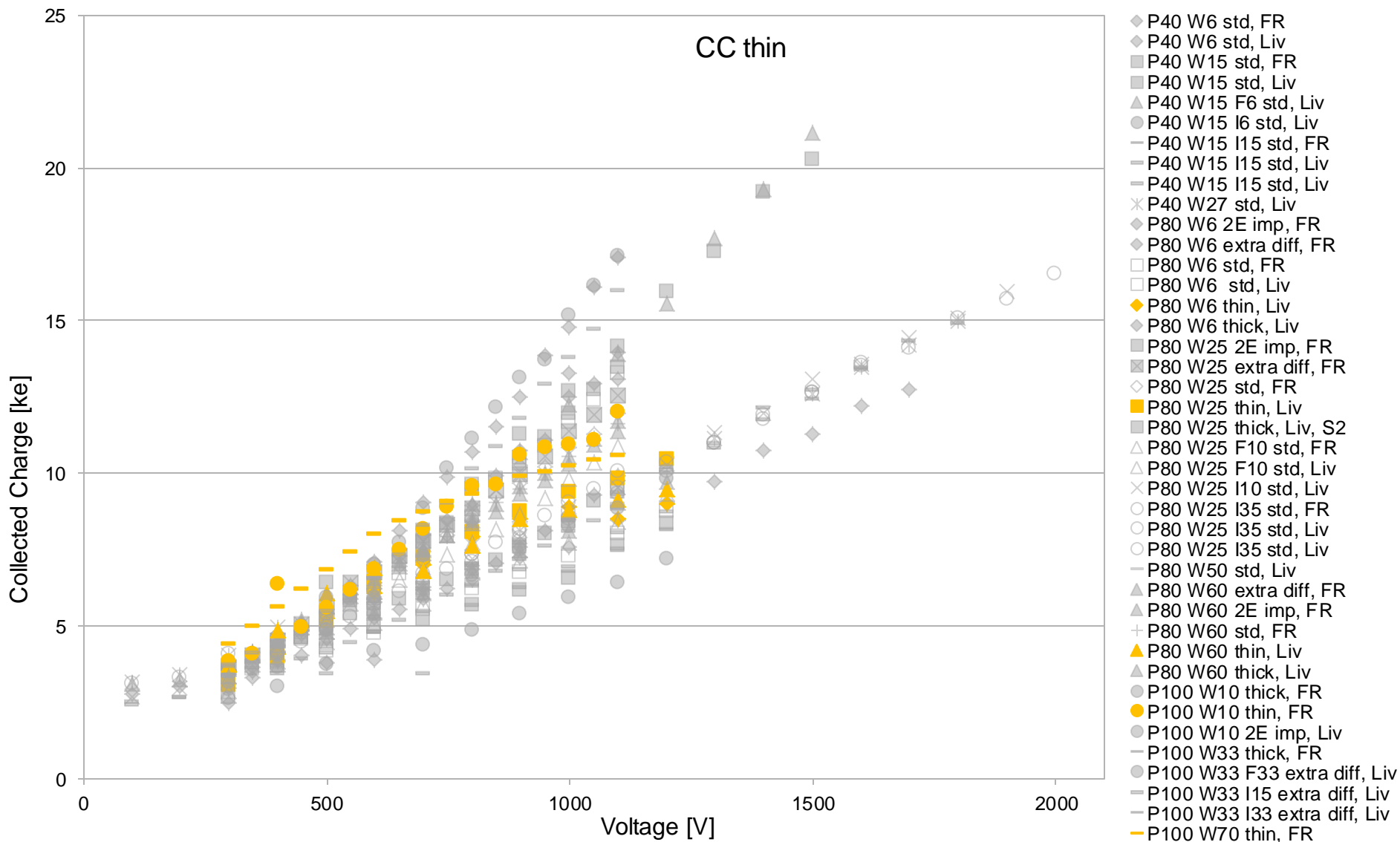


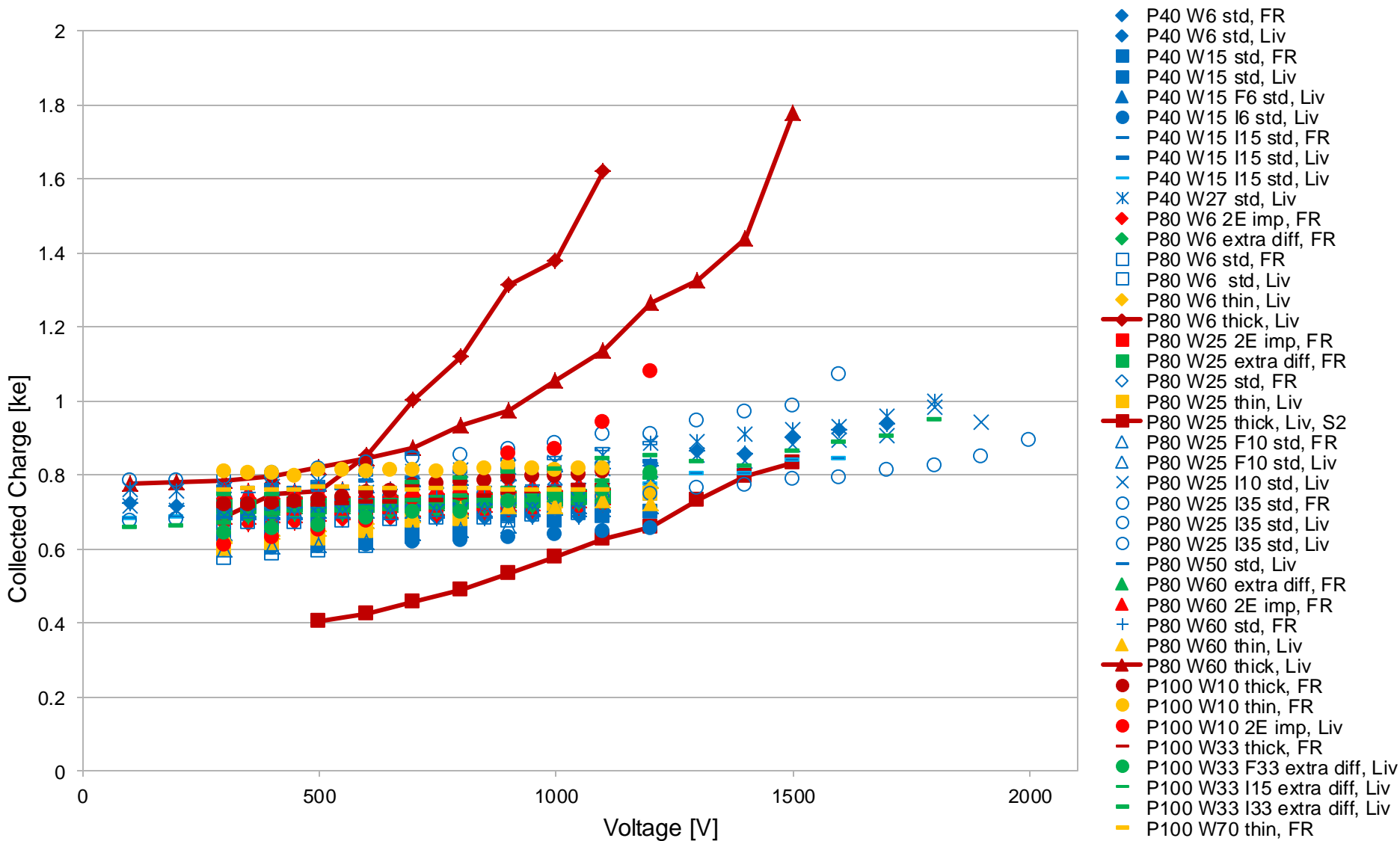


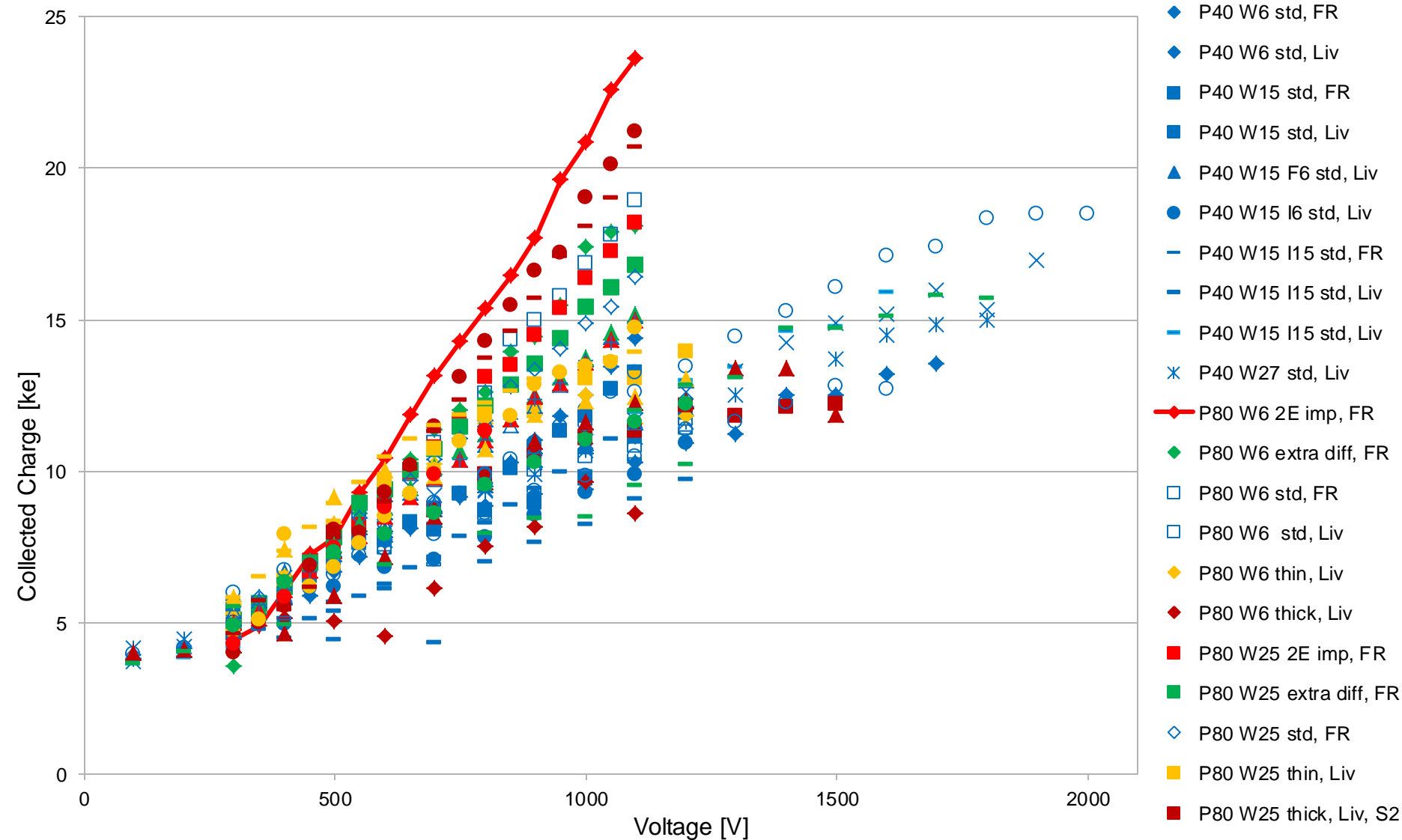










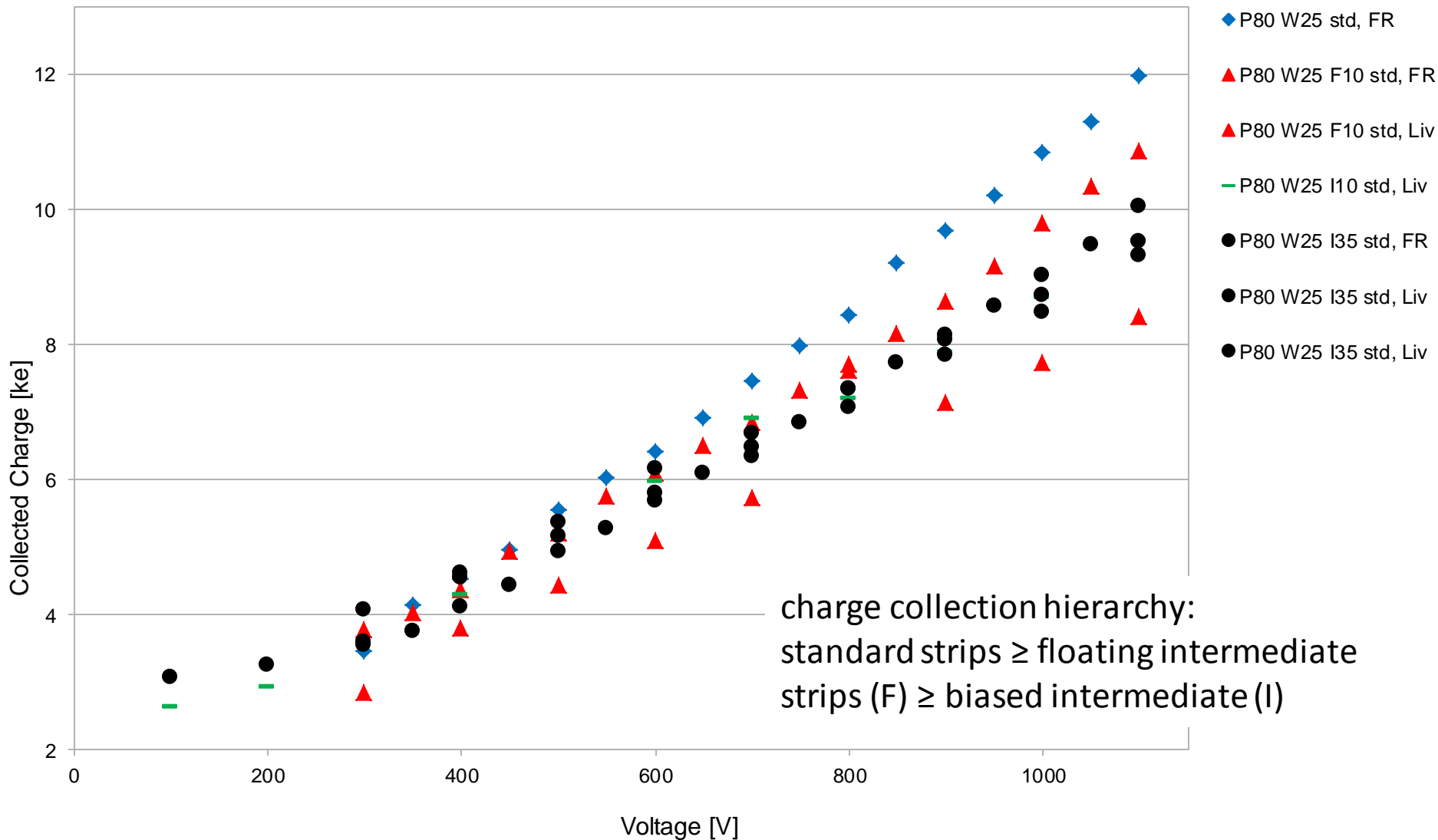




- P80 W6 with double implant energy (2E imp) shows clear signs of charge multiplication past 600V with no significant increase in noise
- In general the double implant energy sensors behave well
- The “thick” sensors show in general higher charge than others above 1000V (P100 W10 and P100 W33 more than P80 W25 and P80 W60)
- Noise below 1ke up to high voltages
- For “thick” sensors P80 W6, P80 W25 and P80 W60 the noise increase for more than 600V
- For all sensors no decrease in SNR seen
- ‘P80 W6 2E imp’ shows best SNR, comparable with the values for lower irradiation dose
- Also the “thick” sensors P100 W10 and P100 W33 show good values
- **P80 W6 (double energy), P100 W10 and P100 W33 (“thick”) are promising candidates for charge multiplication**
- **P80 W60 (“thick”) has high collected charge, but also increasing noise above 600V**

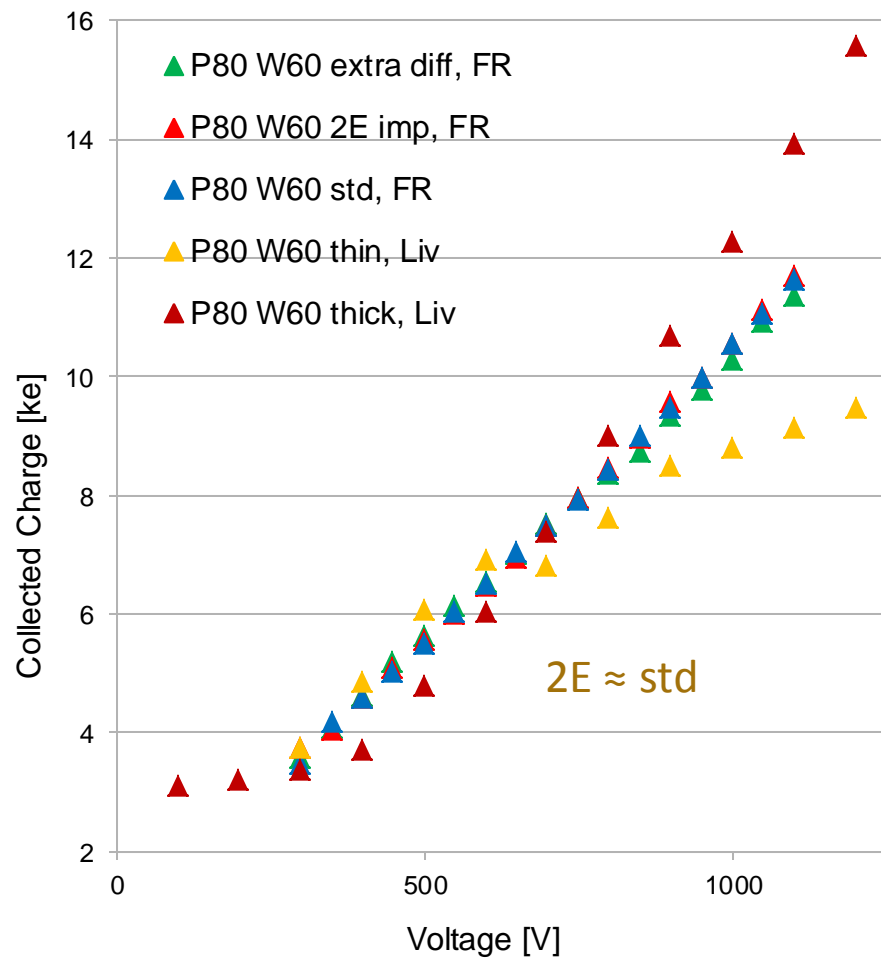
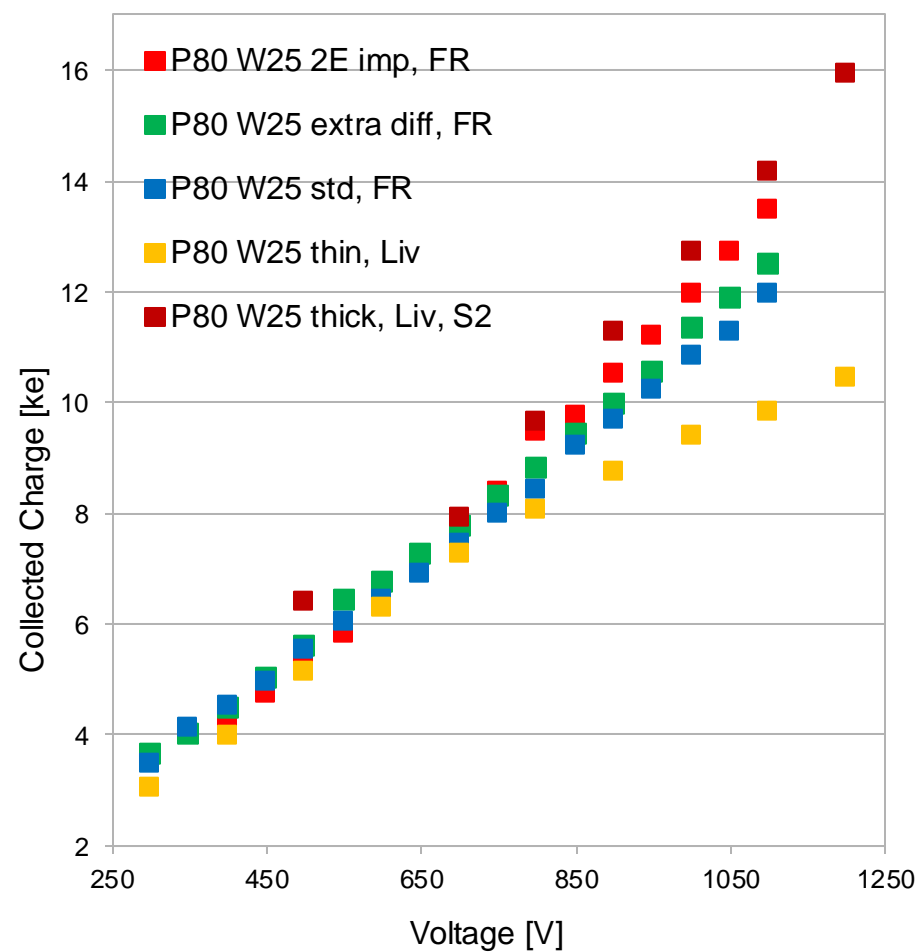


Strip Structure





thick > 2E imp ≥ std ; extra diff > thin
thin starts to saturate





1×10^{15} 1MeV neq/cm²

- P80 W60 shows sign of charge multiplication at bias voltages above 1500V with no significant increase in noise

5×10^{15} 1MeV neq/cm²

- P80 W6 (double energy), P100 W10 and P100 W33 (“thick”) show sign of charge multiplication at voltages above 600V
- Collected charge: standard strips \geq floating intermediate strips \geq biased intermediate strips
- More investigations for double implant energy sensors should be done to confirm their good charge collection.
- No measurements for double implant energy sensors and “thick” sensors at 1×10^{15} 1MeV neq/cm² were done till this day -> should be done to confirm sign of charge multiplication at high dose



Acknowledgements

We would like to thank the
irradiation teams at Ljubljana and
Karlsruhe

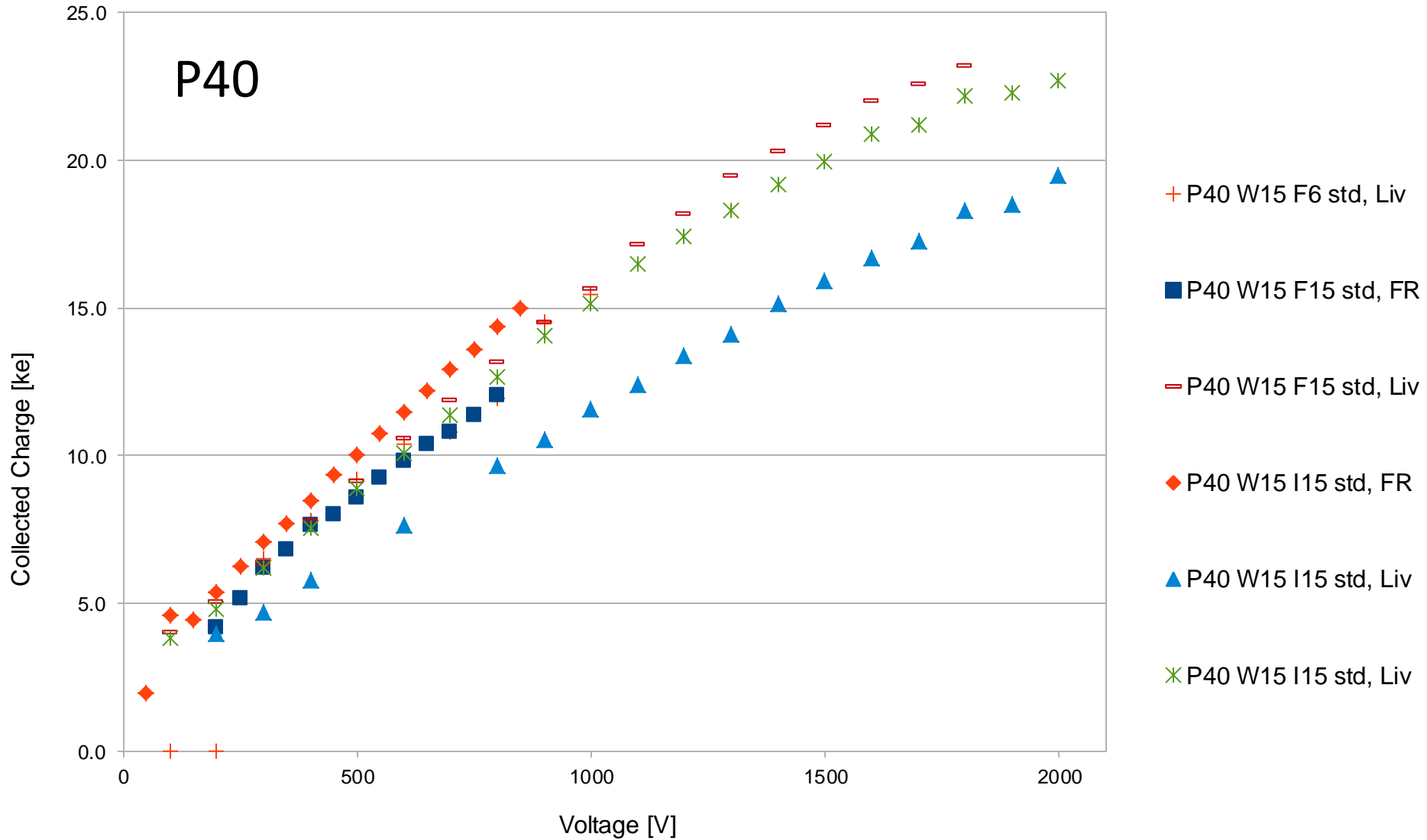
The RD50 community as a whole



Backup

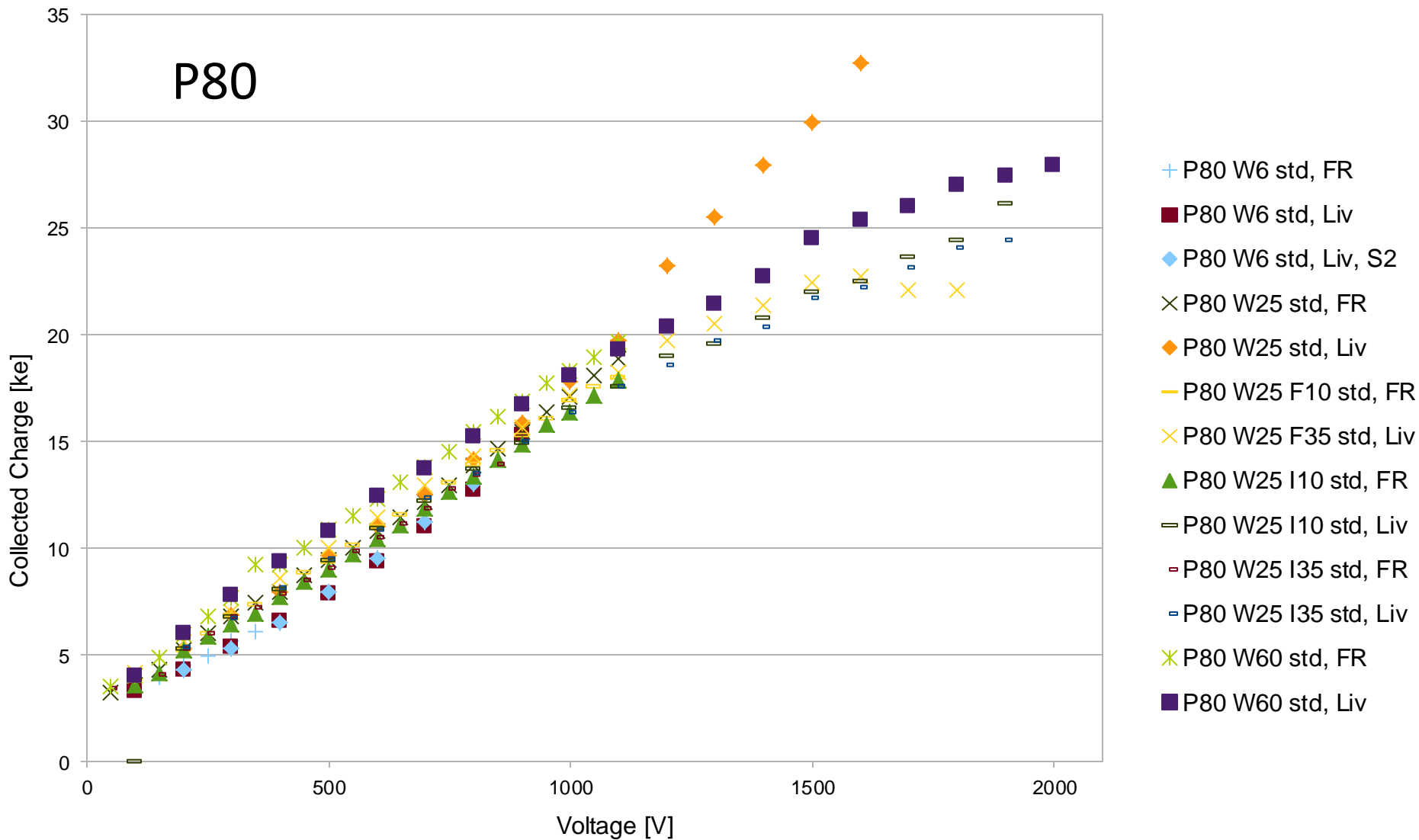


P40



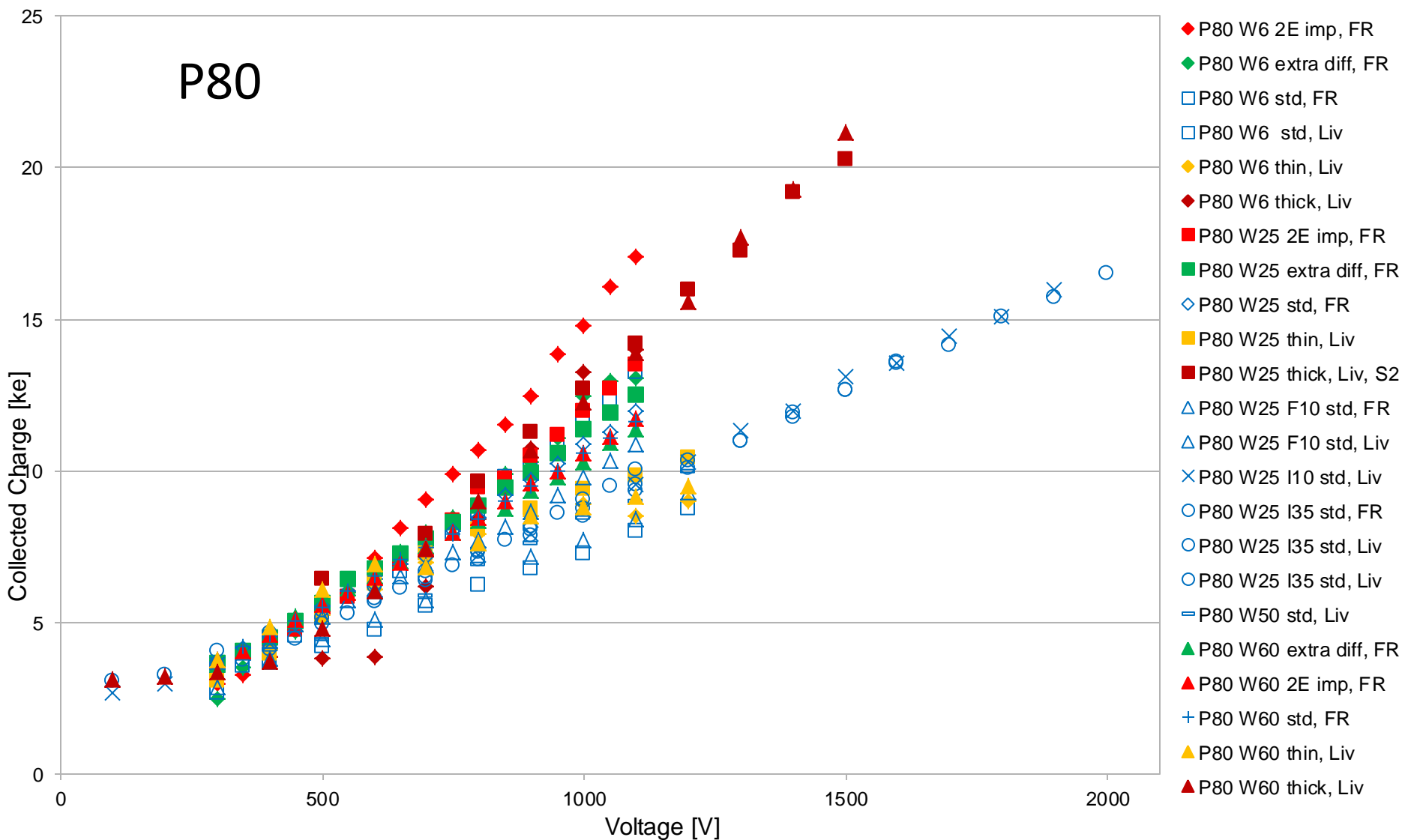


P80





P80





P100

