Update on Charge Explosion: Simulations and Measurements

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1. Summary of Charge Explosion Effects
2. WIAS Cooperation – Status and Outlook
3. Measurements: Making Results comparable
4. Recommendations for AGIPD

Summary of Charge Explosion Effects

- Peak currents > 1 mA
  - Investigation of safety diodes initiated by PSI
- Increase of charge collection time
  - Need to find optimum working point in parameter space (voltage, integration time, design, etc.)
- Increase of lateral spread
  - Directly influencing imaging performance
  - (partly) hidden by large pixels

All Information can be gained by evaluating current pulses

WIAS Cooperation

Aim: Provide numerical tool to simulate pulse shapes with plasma effects for structures with complex 3D geometries

Status so far:

- Solved numerous implementation problems
- Agreements on set of reference measurements
- Simulation results for reference measurements
- Qualitative understanding reached
- Fine tuning of a limited number of parameters needed

WIAS Cooperation: Outlook

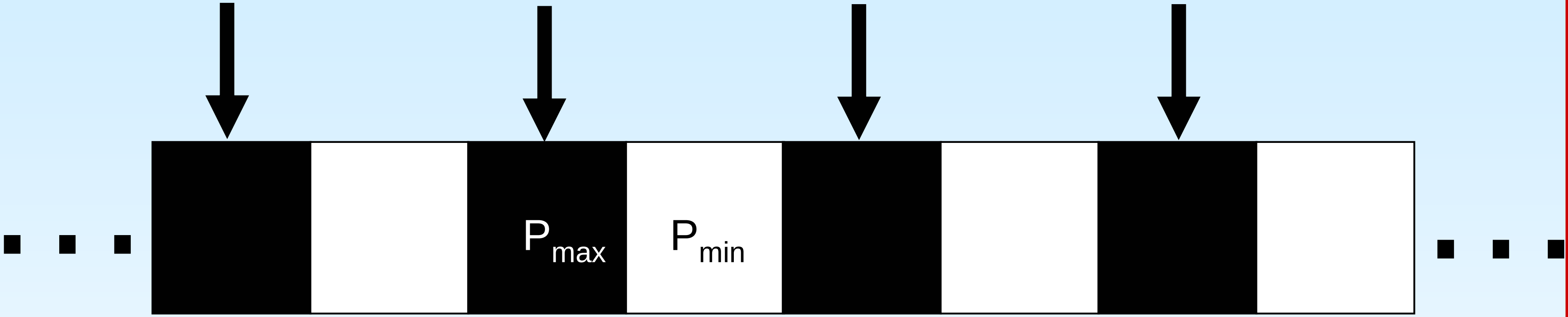
- Paper on plasma effect in pad diodes and the simulation code in preparation (proof of principle)
- 2nd paper with results on strip sensors and details on spatial distributions in planning phase
- Open points accessible by simulations:
  - Angular effects
  - Different energies (e.g. 8 keV)
  - Other layouts, pixel sizes, etc.
  - Big XFEL-like spots (5x5x5 Ferritin)

Making results comparable: problems

- Measurement data for test structures with different layouts than final AGIPD sensor
  - Need to find results that can be extrapolated to the AGIPD design
- Results must be quantifiable for comparison
- Impact on science of experiments should be estimated
  - Need to know experiments
  - no coherent set of requirements from experiments

No Problem for peak currents and collection times!

Comparing lateral spread by contrast

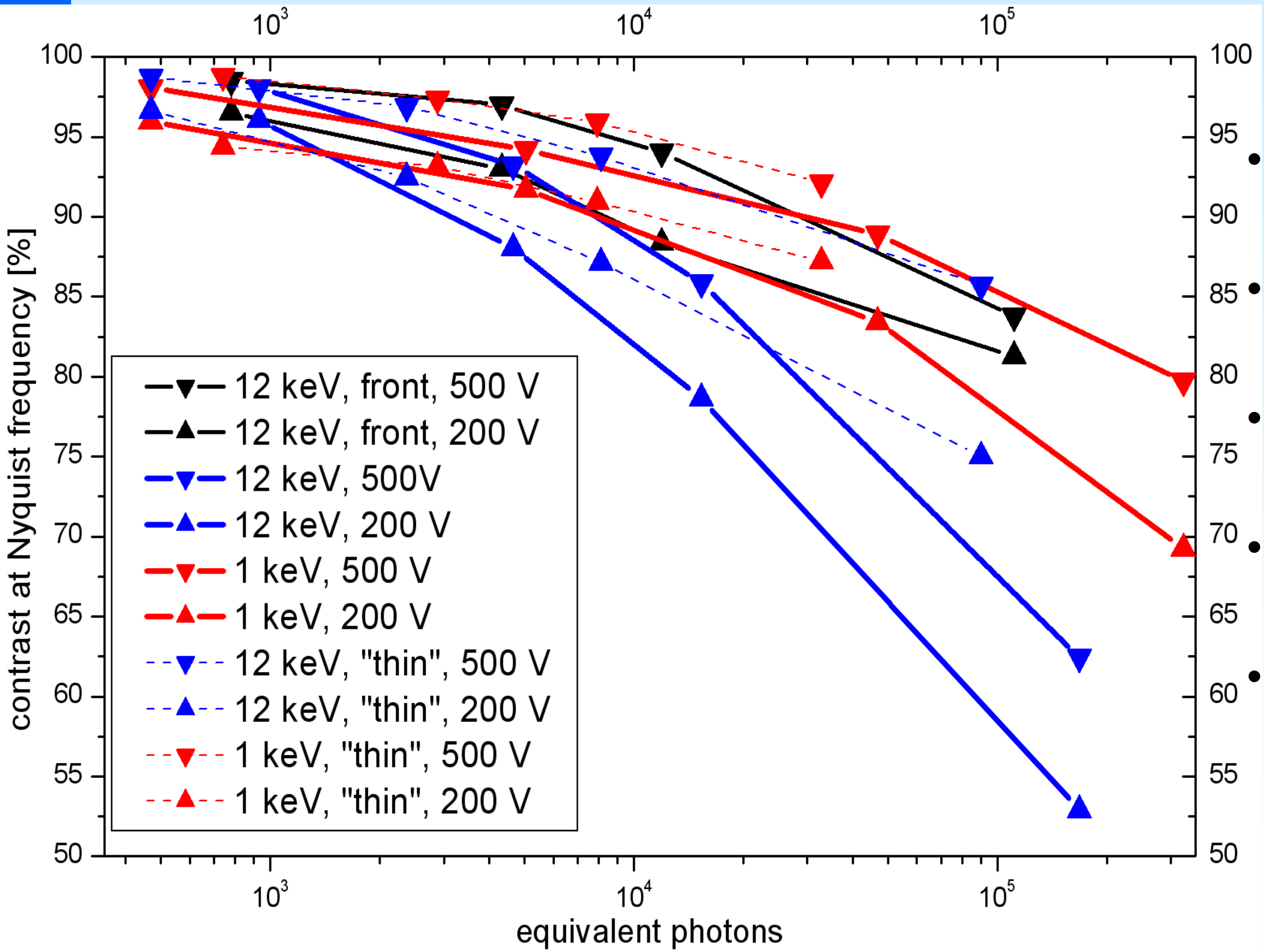


$$contrast = \frac{P_{\max} - P_{\min}}{P_{\max} + P_{\min}}$$

Contrast at Nyquist frequency (alternating black/white pattern) measures the imaging performance

Range from 0 (same charge everywhere) to 1 (all charge in pixel, none in-between)

Contrast



- decreases for higher intensities
- larger for larger energies
- increases with increased voltage
- higher in thin sensors (280 µm)
- higher for front side injection

Front side injection similar to (not the same as!) n-in-n layout

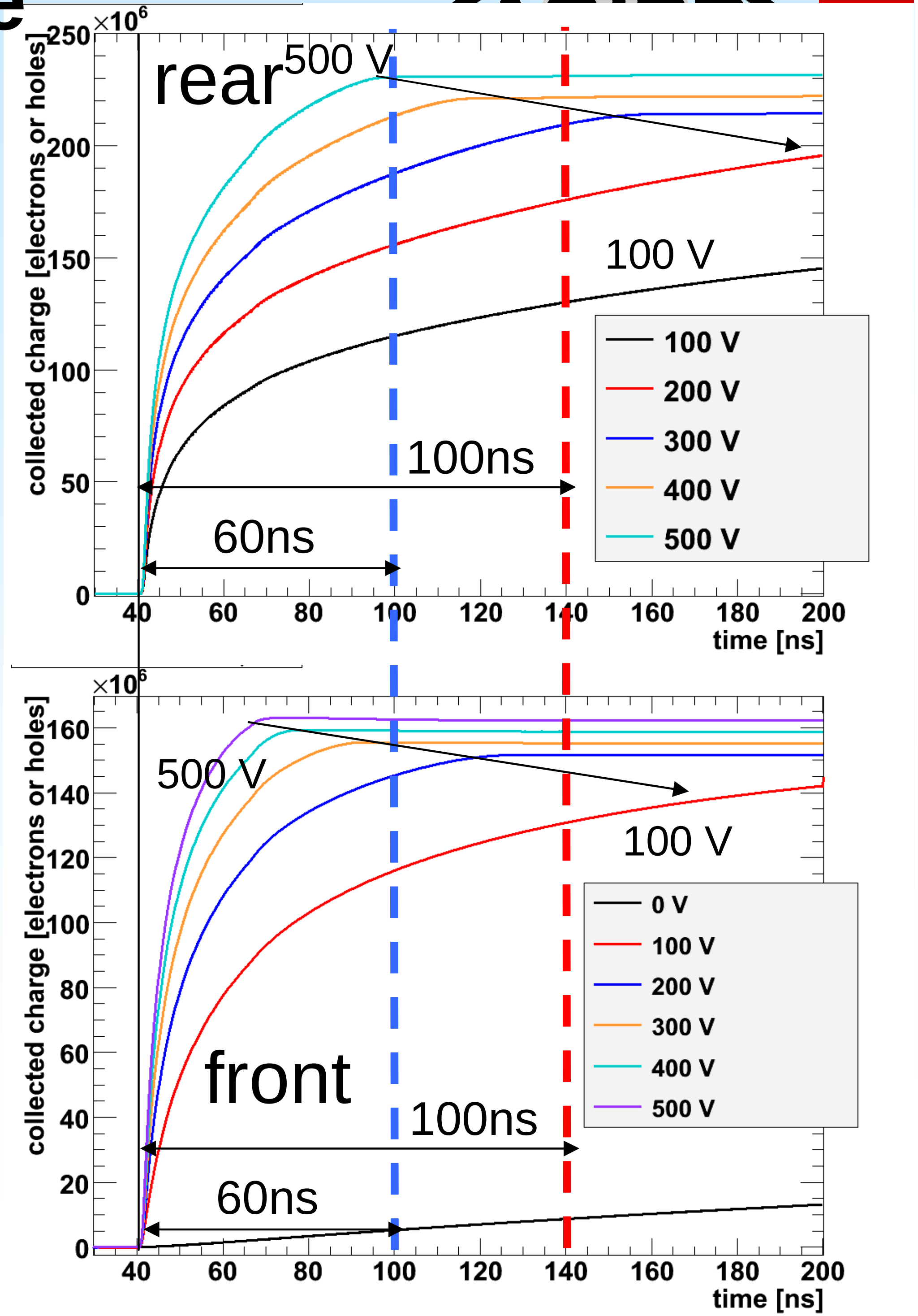
Charge collection time

1.68 x 10^5 12 keV Photons
(rear, σ≈3 µm, 450 µm sensor)

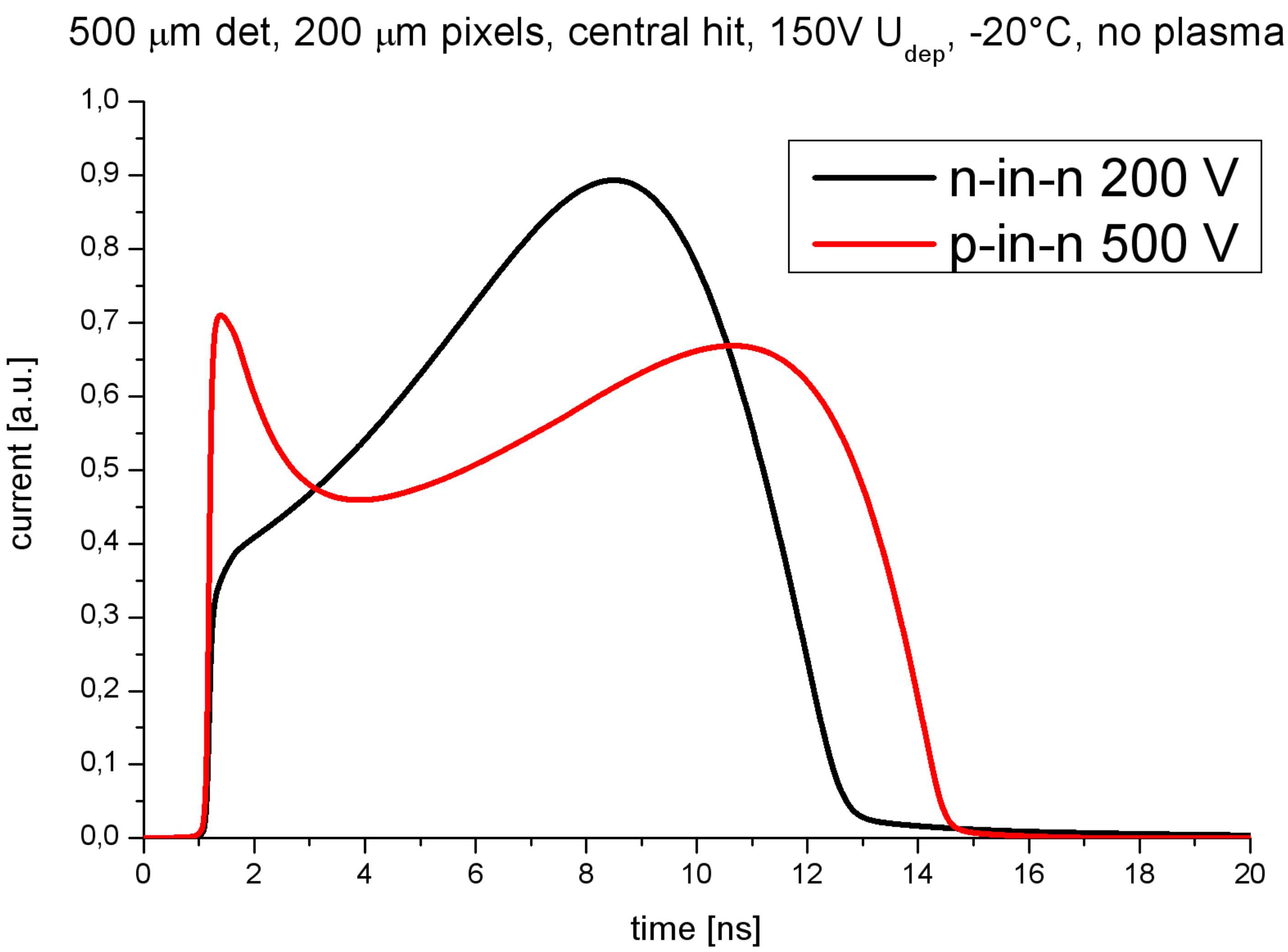
1.11 x 10^5 12 keV Photons
(front, σ≈3 µm, 450 µm sensor)

front side injection clearly favored!

- 100 % charge collection (no pile-up)
- within 100 ns
- already for 200 V!



Charge collection time, no plasma effect



- Simulation
- 200 μm Pixels
- -20°C
- same sensor parameters
- different readout type
- voltage sufficient for 100 % charge collection

Pulses of similar length for n-in-n layout (at 200 V), no additional problems with gain switching expected

Additional effects of n-in-n vs. p-in-n

- electron collection
  – opposite polarity of pulses w.r.t. p-in-n
  – more diffusion (+70% diffusivity, i.e. charge sharing)
- no HV on edges, no risk of sparking to ASIC
- HV proven design (e.g. CMS-Pixel, Atlas-Pixel)
- p-stop/p-spray isolation between pixels needed
  – needs to be tested for radiation damage
- double sided processing needed
  – higher cost w.r.t p-in-n, but still small comp. to bump bonding
  – less manufacturers/vendors

Recommendation from plasma point of view

1. n-in-n design, 500 µm, 200 V, 80 ns
   - explained on previous slides
   - lowest peak current
2. p-in-n design, 500 µm, 500 V, 100 ns
   - HV sparking issue still unresolved
   - highest peak current
3. p-in-n design, 500 µm, 300 V, 140 ns
   - less peak current