Sensors Update

(VR for the Sensor Group)
October 17, 2005

- Overview of Sensor Requirements and Some Key Technology and Performance Issues:
  - ***QE***
  - ***sensor thickness and PSF***
  - ***depletion and electric field***
  - ***window ohmic contact***
  - ***QE below 400 nm***

- Sensor R&D plan

- ***Status of Sensor Study Contracts with Potential vendors***

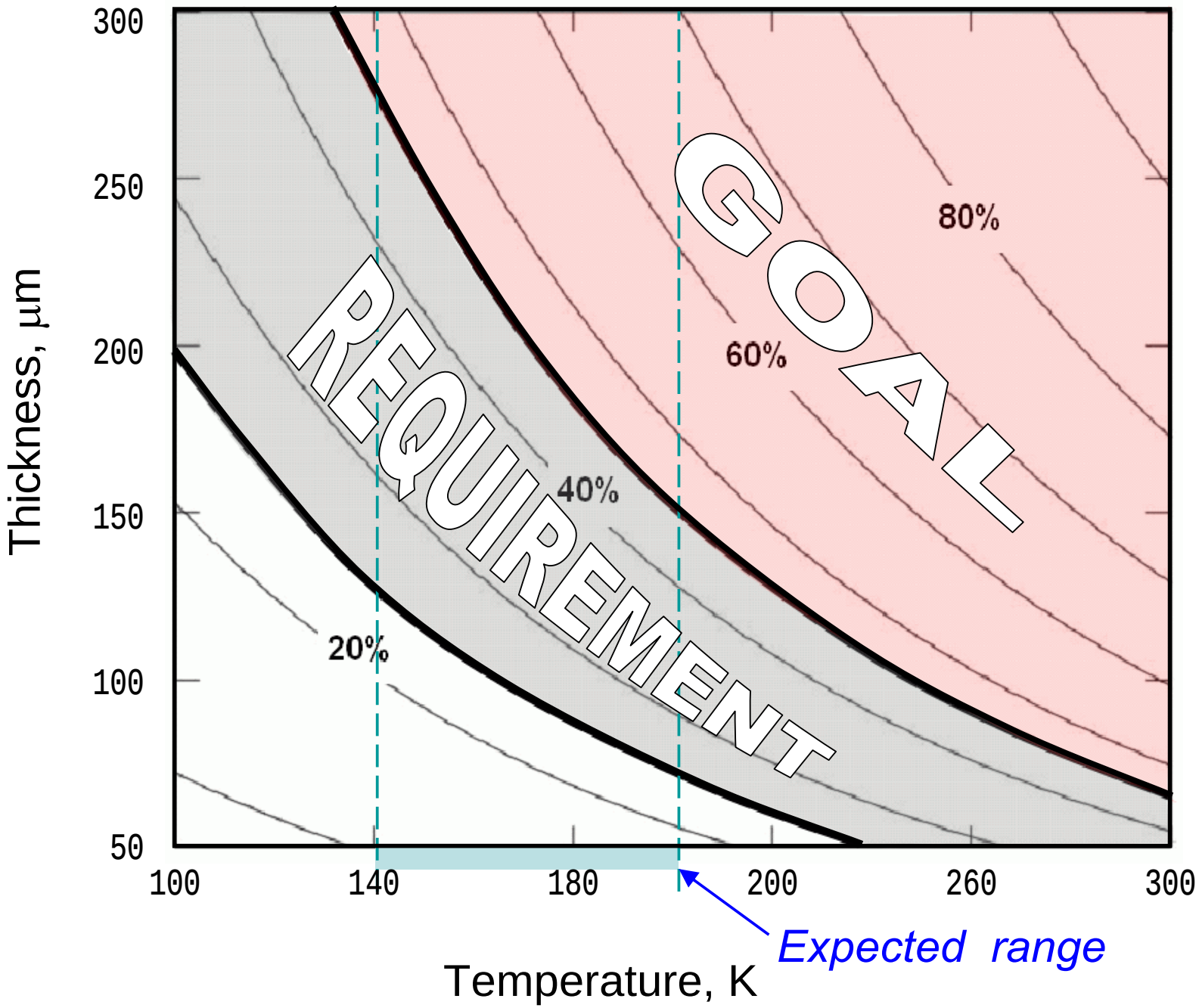
Sensor thickness study:

[1] "Study of Silicon Sensor Thickness for LSST", LSST Knowledge Center, also at: http://www.inst.bnl.gov/~poc/LSST/Study%20of%20sensor%20thickness.doc

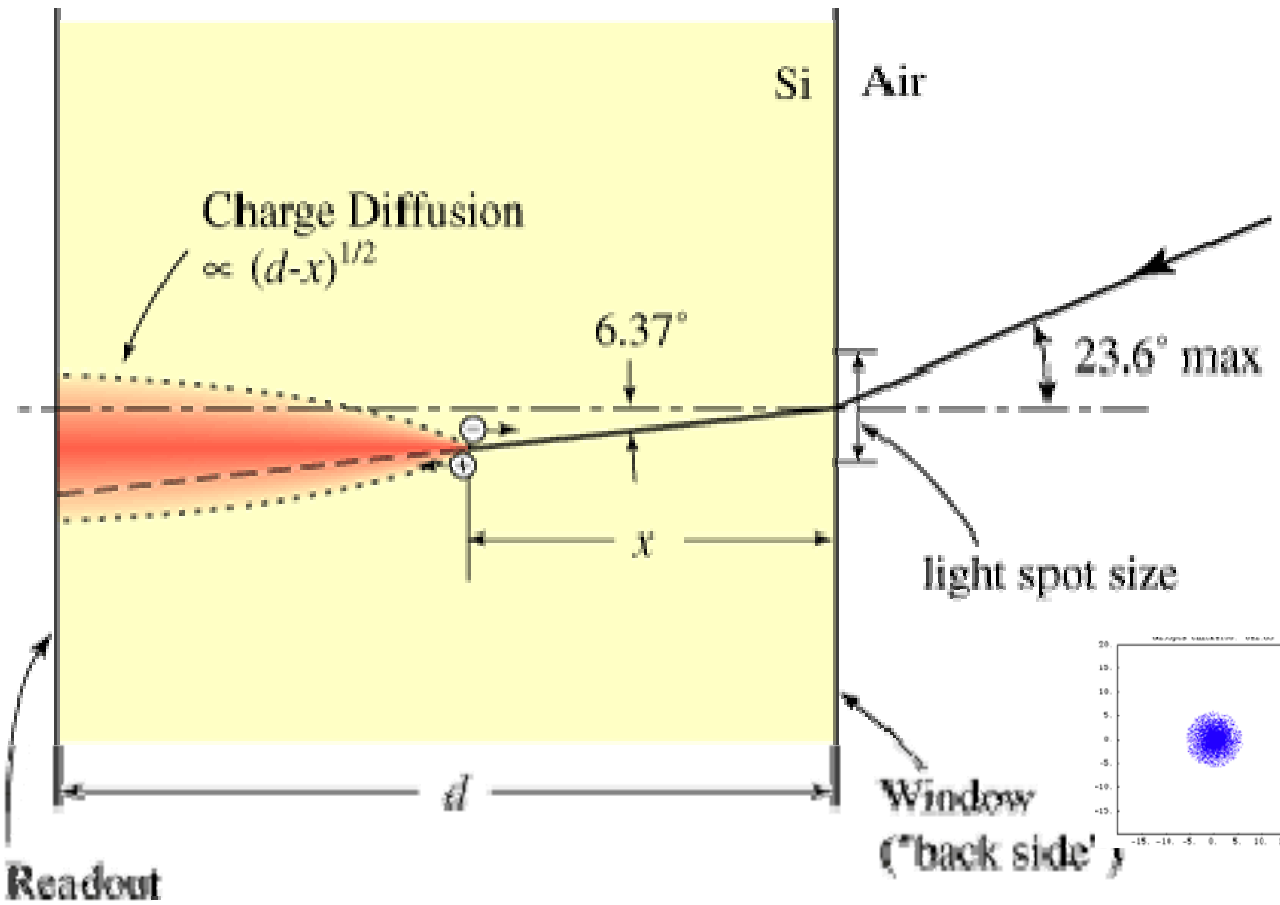
From LSST Science Reqts to Sensor Reqts

- High QE to 1000nm ➔ ***thick silicon (> 75 µm)***
- PSF << 0.7" (0.2") ➔ high internal field in the sensor
  ➔ ***high resistivity substrate (> 5 kohm·cm)***
  ➔ ***high applied voltages (30 - 50 V)***
  ➔ ***small pixel size (0.2" = 10 µm)***
- Fast f/1.2 focal ratio ➔ ***sensor flatness < 5µm***
  ➔ package with piston, tip, tilt adj. to ~1µm
- Wide FOV ➔ ~ 3200 cm^2 focal plane
  ➔ > 200-CCD mosaic (~16 cm^2 each)
  ➔ industrialized production process required
- High throughput ➔ > 90% fill factor
  ➔ 4-side buttable package, sub-mm gaps
- Fast readout (1 - 2 s) ➔ ***segmented sensors*** (~6400 TOTAL output ports)
  ➔ 150 I/O connections per sensor
- Low read noise ➔ < ~ 5 rms electrons

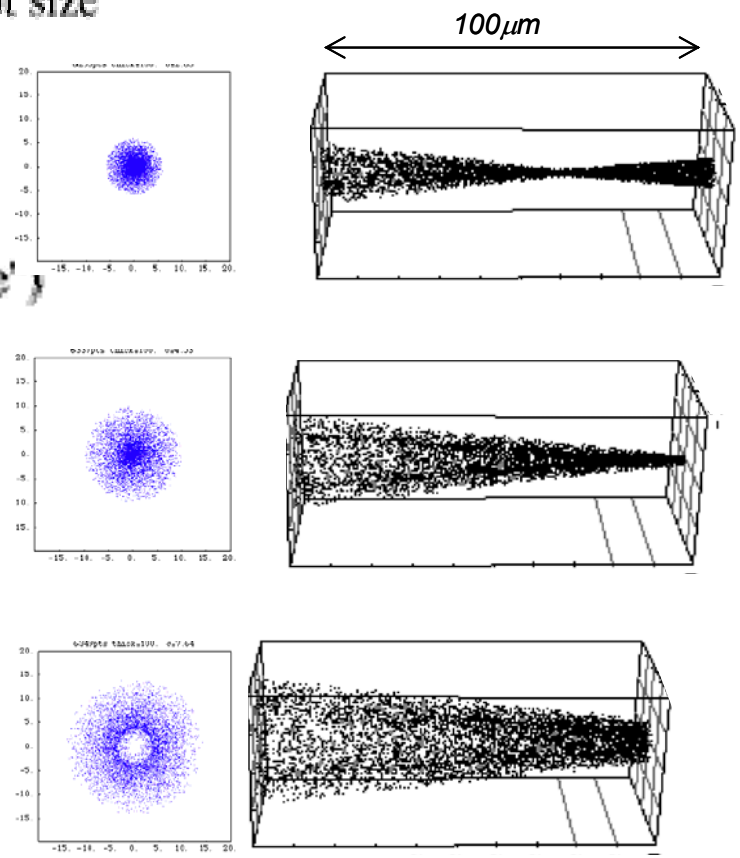
QE at 1000nm vs. thickness, temperature



Point Spread Function (PSF) in Si



Simulation by P. Takacs, BNL:



FP displacement: +10μm

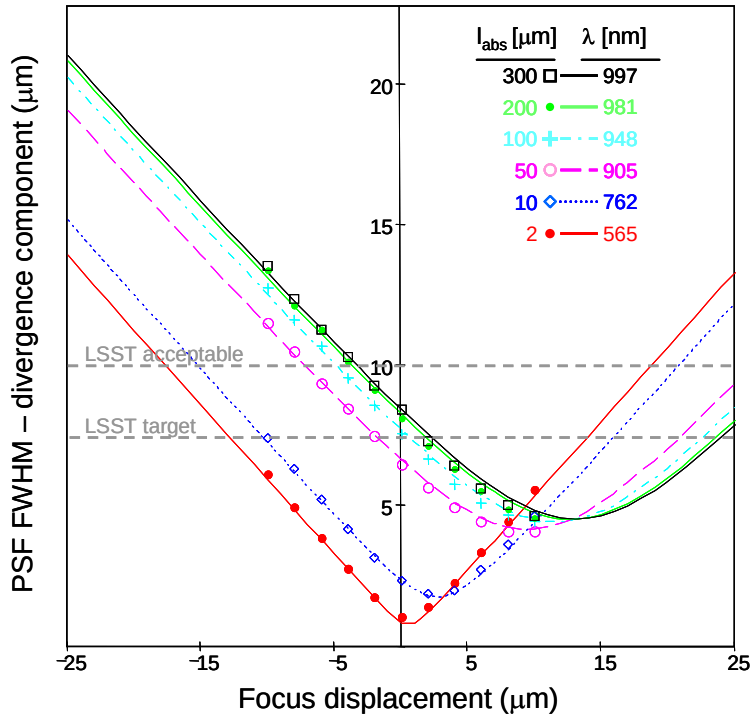
0μm

-10μm

Light spot, cone, absorption→ionization, charge diffusion → PSF

Point spread function dependence on focal plane position.

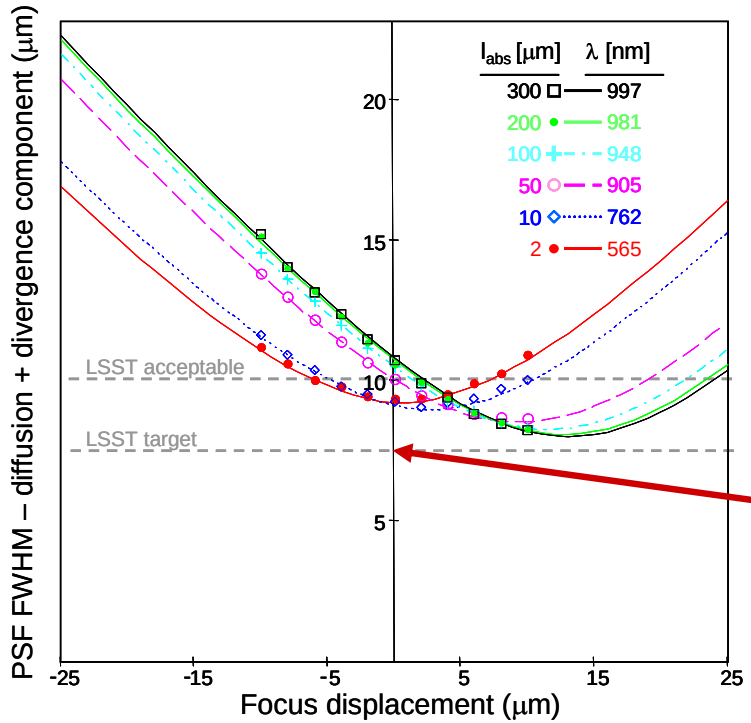
(a)



Diffusion *not included*

Importance of diffusion!

(b)

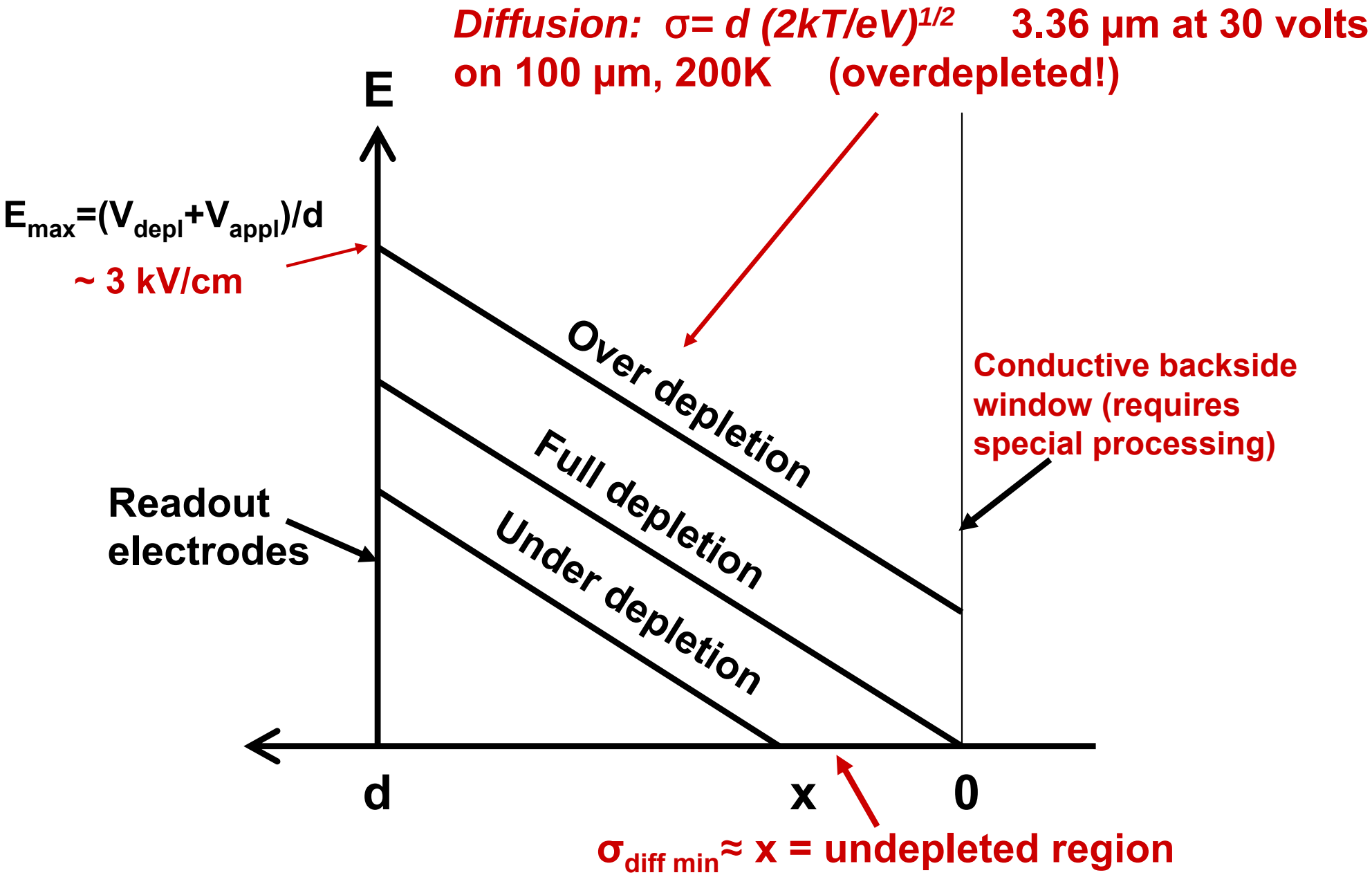


Diffusion *included*

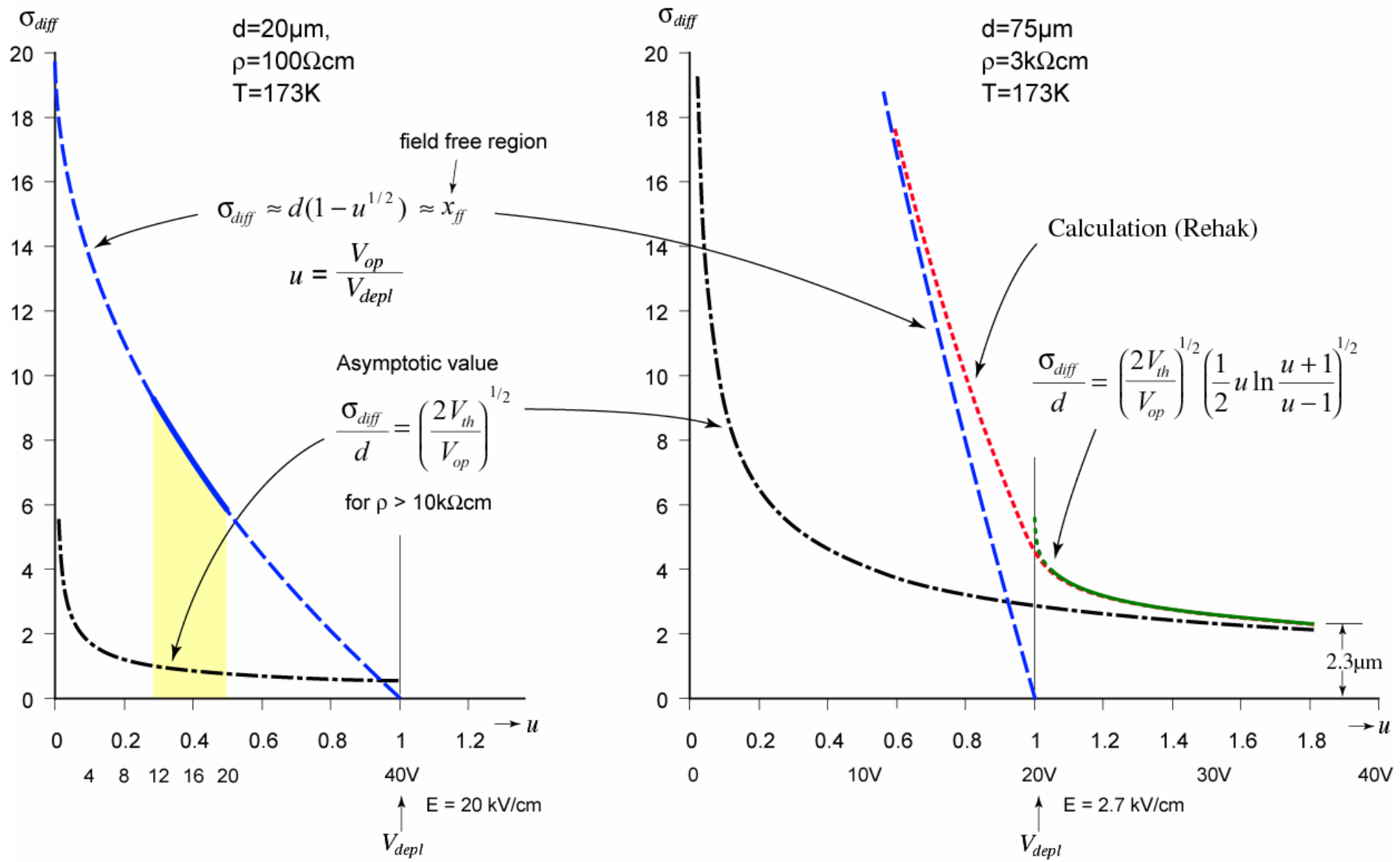
Positive displacements move the focal point into silicon volume. Sensor thickness **100μm; 20 V**; average electric field 2 kV/cm; 173K.

At ≥ 30 V PSF at < ~ 760 nm will be ≤ 7.5 μm (LSST target)

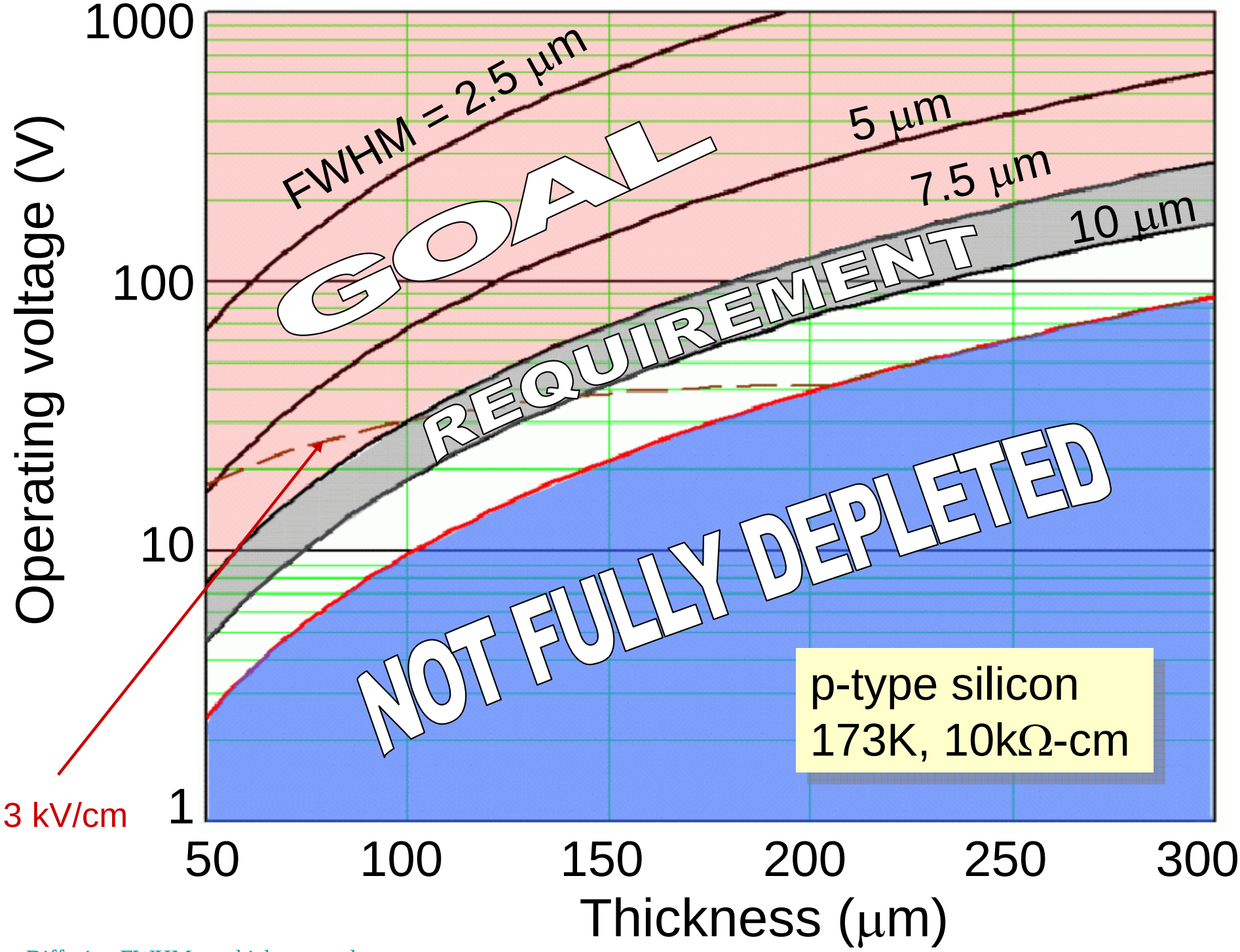
Importance of (over)depletion for PSF



PSF(rms) *vs* V_{op} and *rho* (ρ)

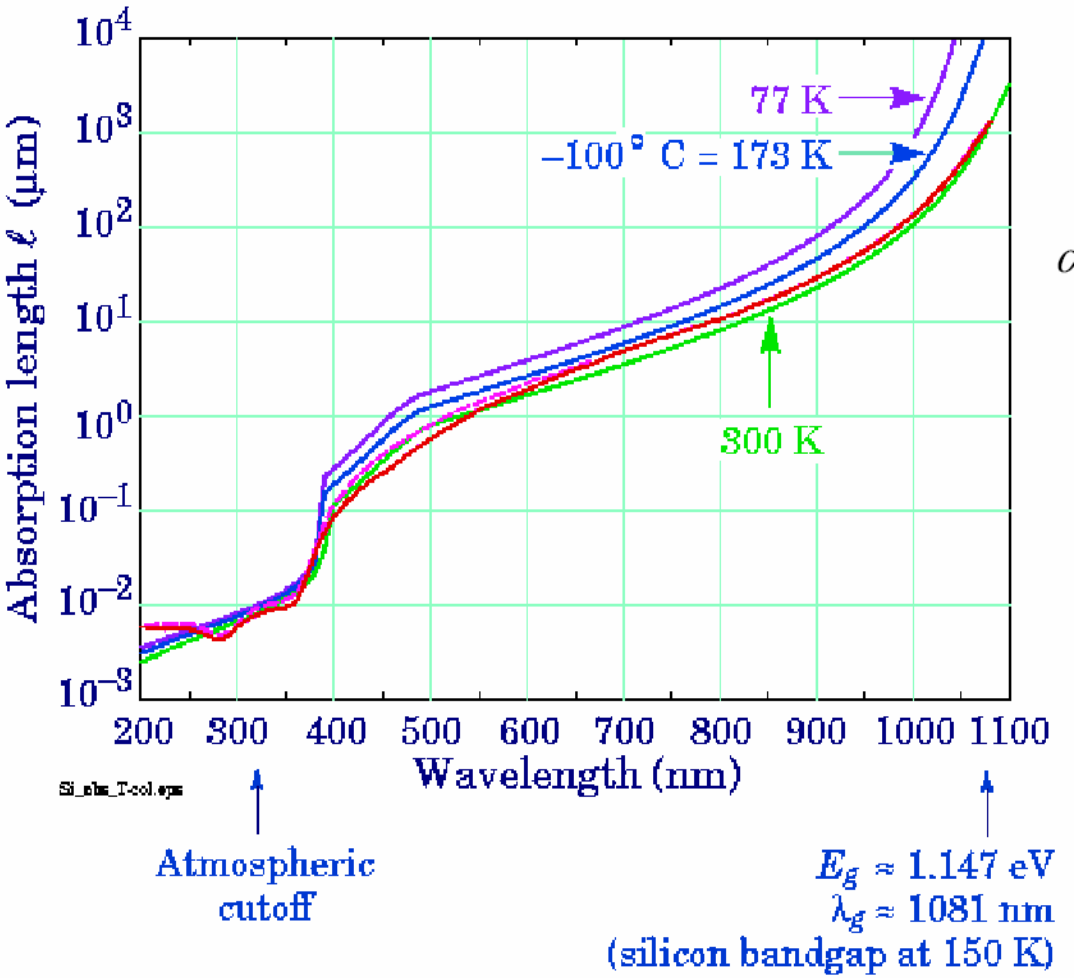


V. Radeka, 01/05



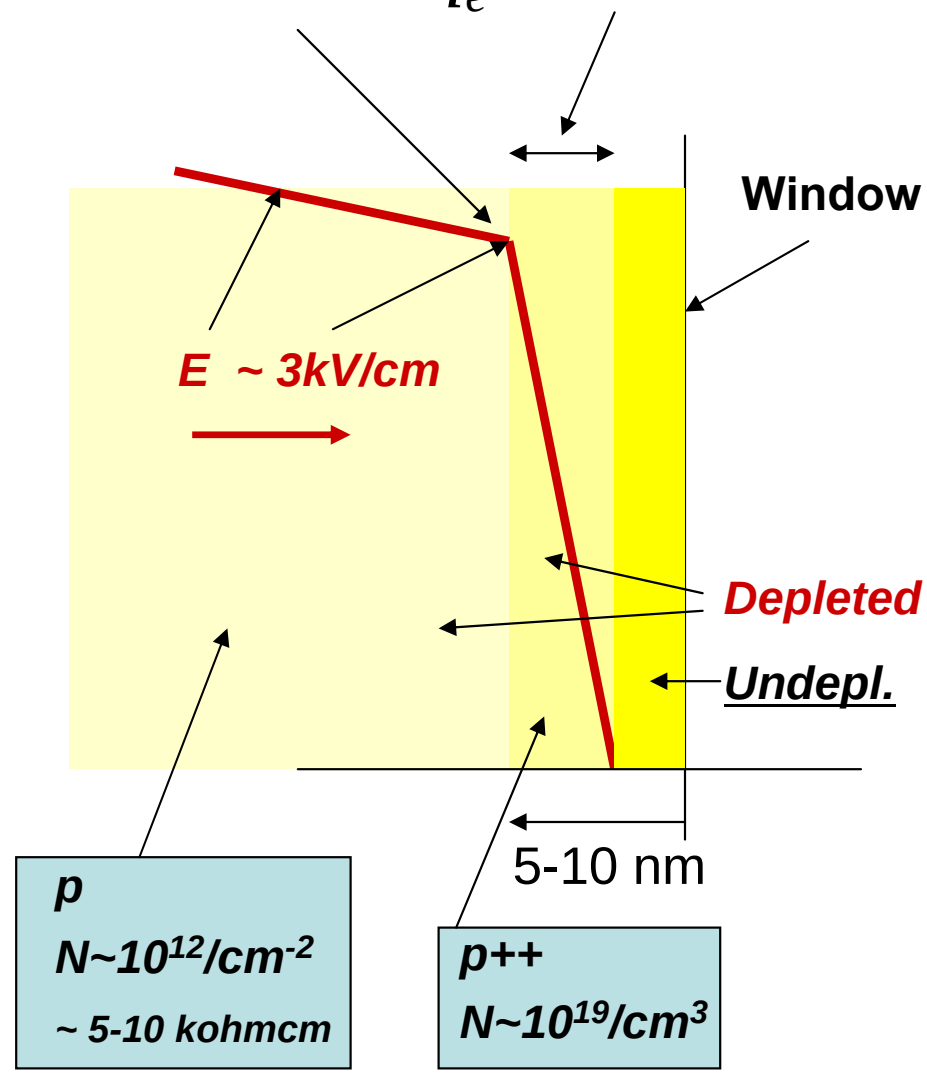
Diffusion FWHM vs. thickness, voltage

The ***uv*** question: absorption length *vs* window technology



"Ohmic contact":

$$\varepsilon E = q_e N \Delta x$$



Advances in State-of-the-Art needed for LSST Detector

- The focal plane array will have about an order of magnitude larger number of pixels ***(~3 gigapixels)*** than the largest arrays realized so far.

- The effective pixel readout speed will have to be about two orders of magnitude higher than in previous telescopes in order to achieve a readout time for the telescope of ***~1 - 2 seconds .***

- The CCDs will have to have an active region ***~100 µm thick*** to provide sufficiently high quantum efficiency at ~1000 nm, and they will have to be (over)depleted so that the signal charge is collected with minimum diffusion as needed to achieve a narrow point spread function.

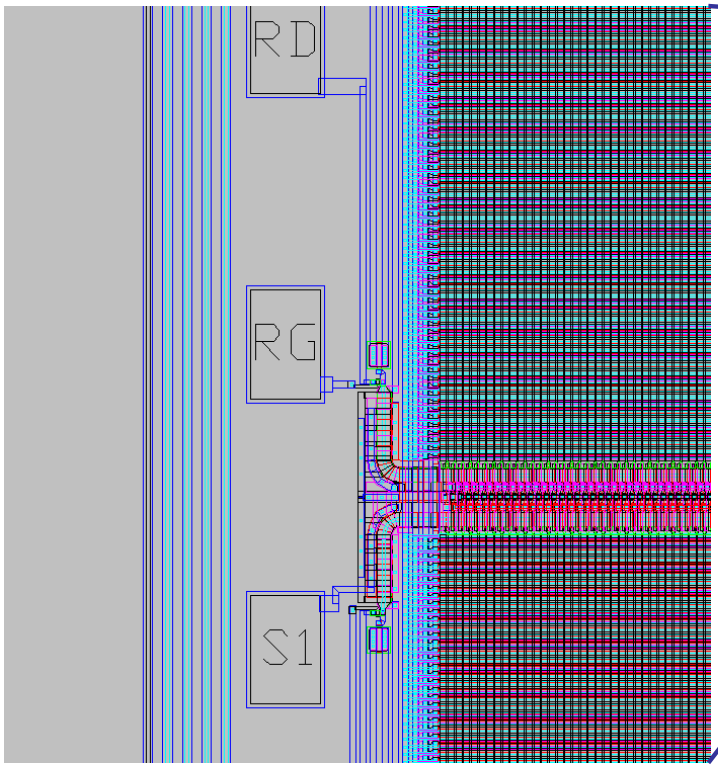
- Packaging ensuring sensor flatness and alignment in focal plane to ***<5µm*** (not routinely achieved with presently delivered devices by industry).

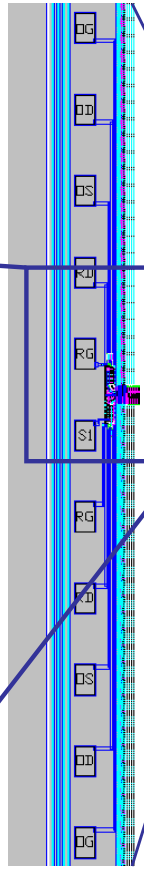
- ***Extensive use of ASICs*** to make the readout of a large number of output ports practical, and to reduce the number of output links and penetrations of the dewar.

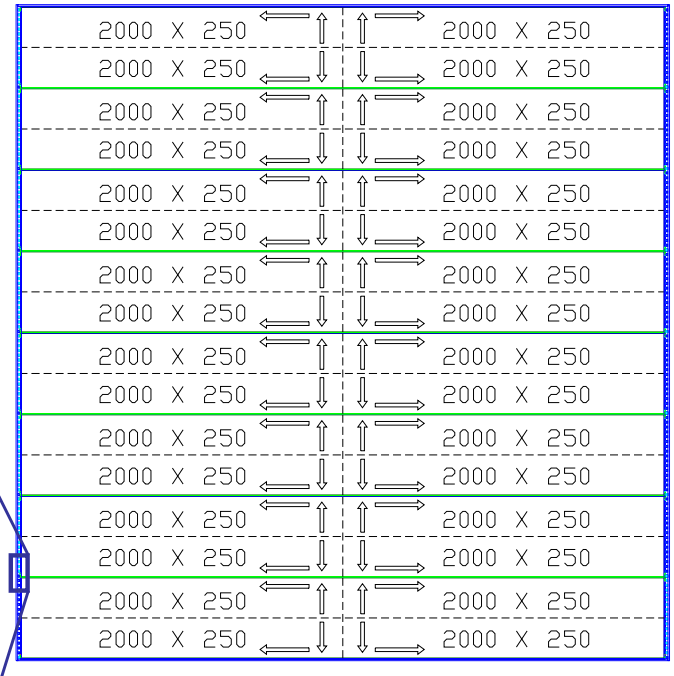
Multi-port 4K x 4K = 16M CCD strawman

32 segments/ports

Detail of output port







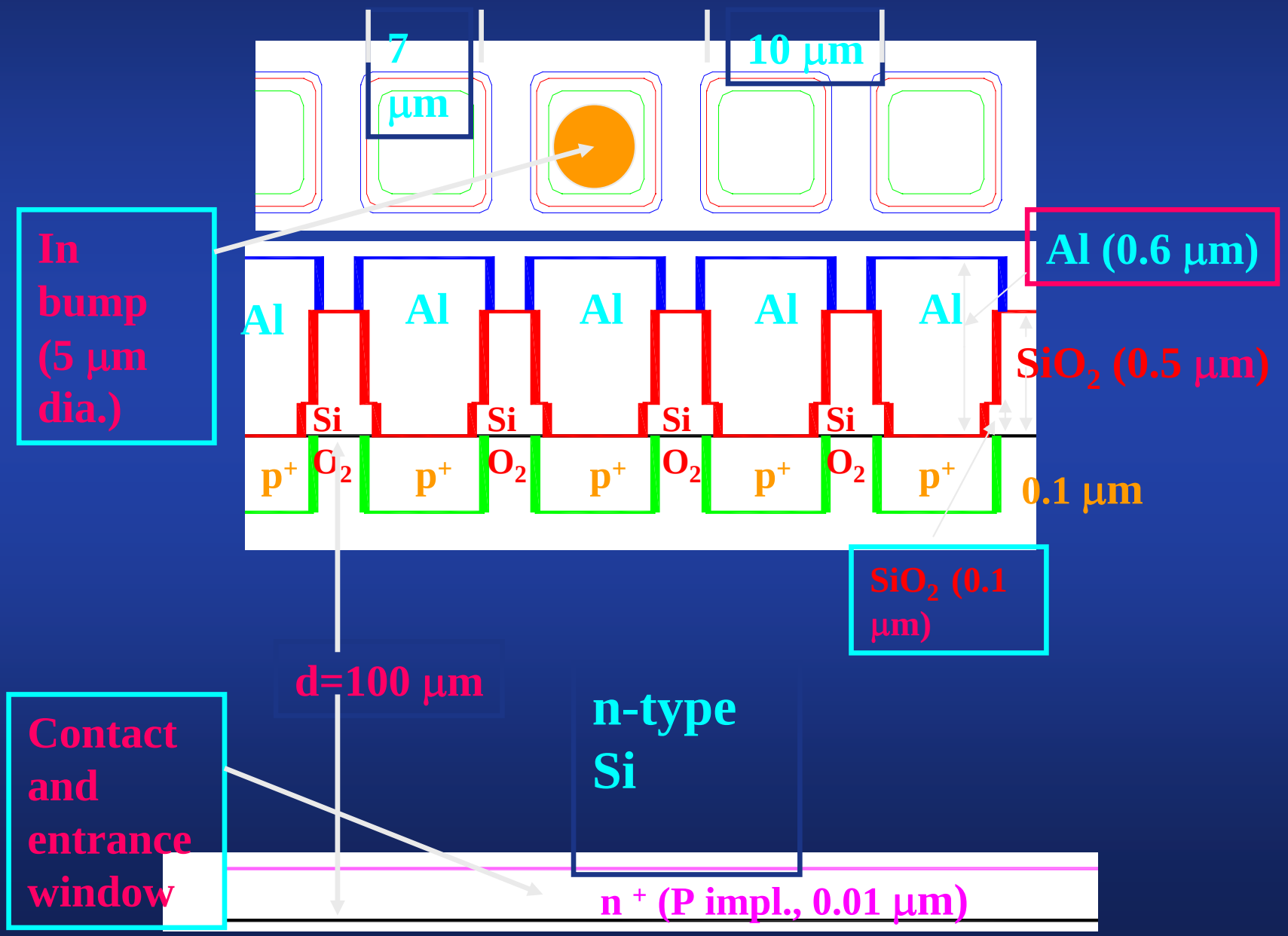
Full CCD showing segmentation. Note pads on left and right edges only

Detail of one edge

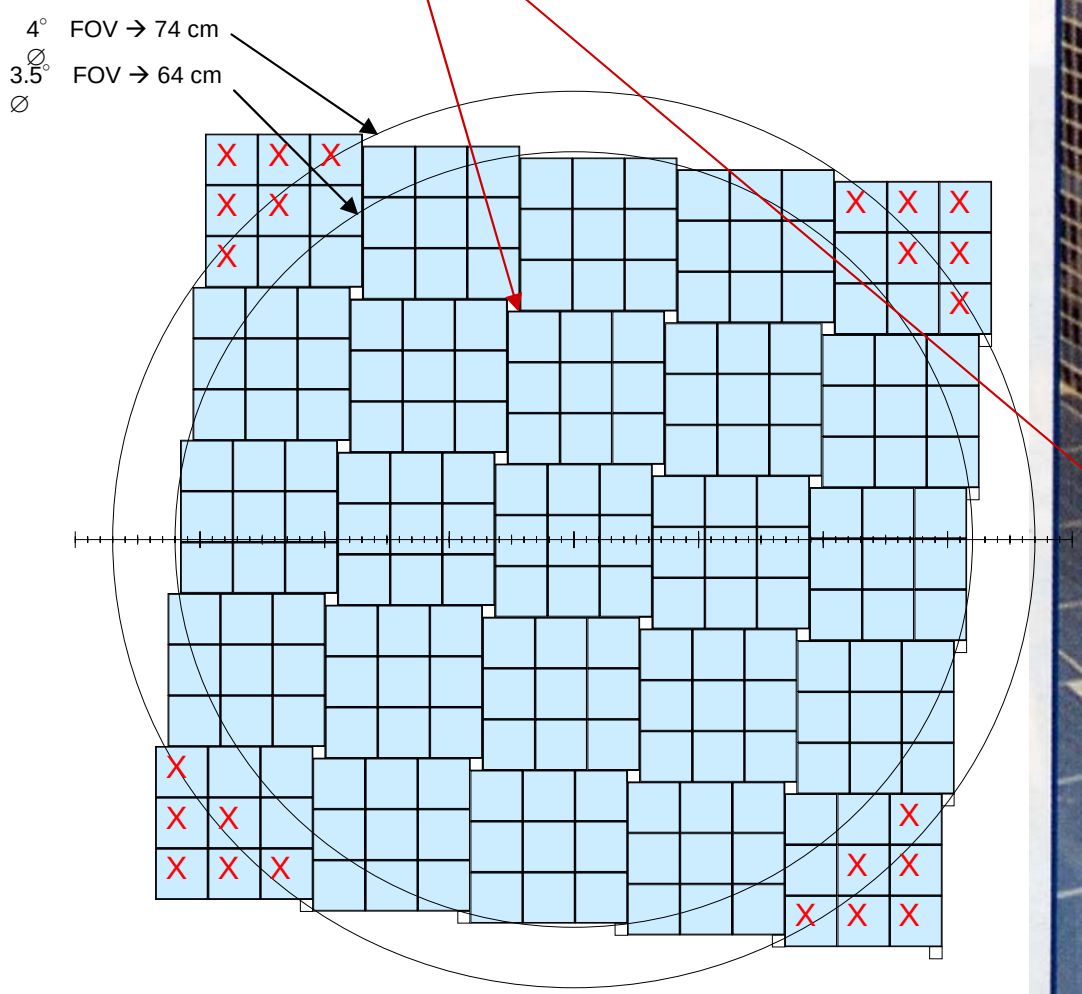
Strawman has 208 bonding pads total

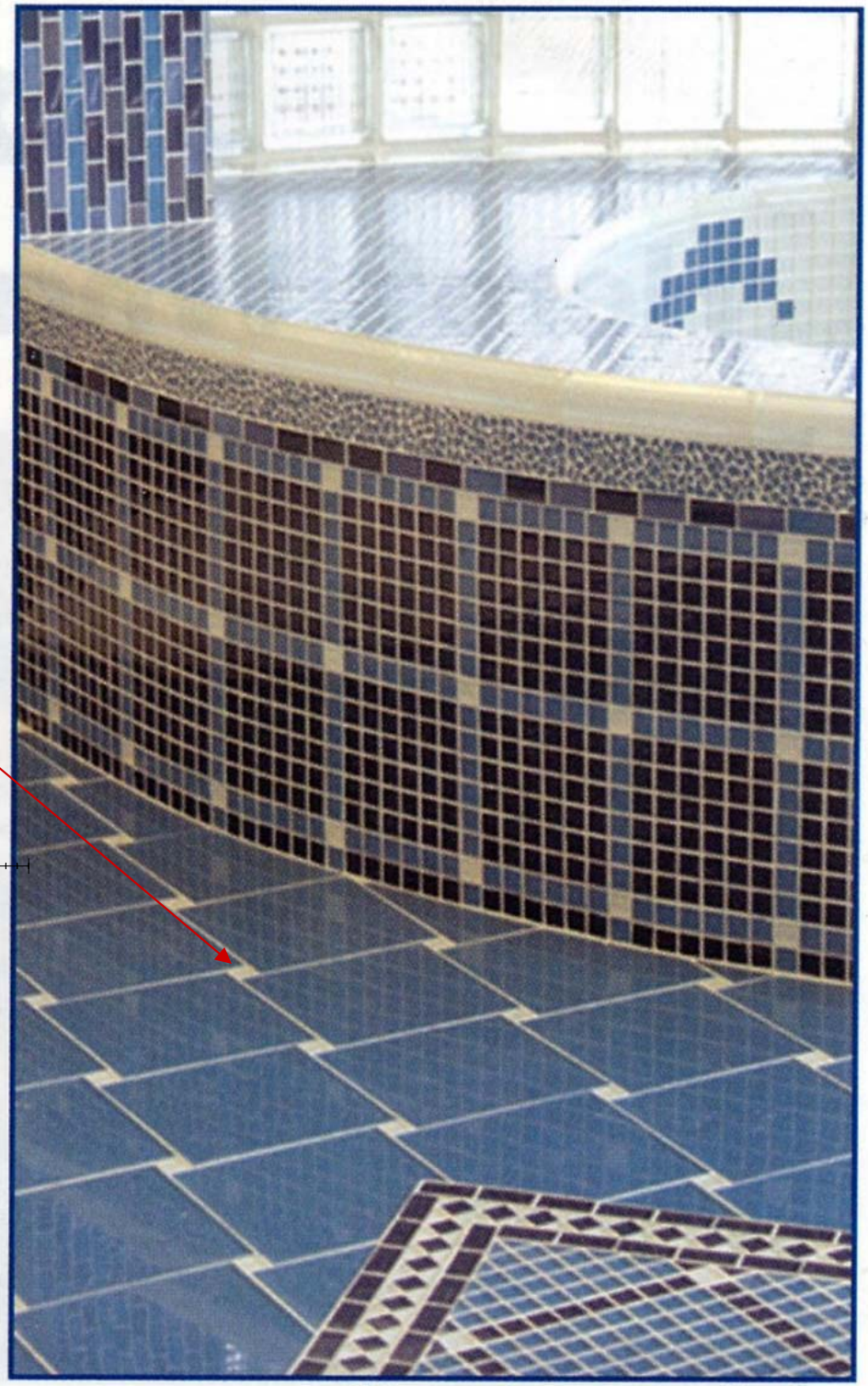
J. Geary, “LSST Strawman CCD Design”, Dec. 2004

High resistivity (5 kΩcm) PIN detector array, fully depleted (V_{depl}~7 V), to be bonded to CMOS readout



3 x 3 sensor rafts in the focal plane with areas provided for wavefront sensors by raft offset.





Cancos Tile - Glass showroom display

LSST Sensor Development Program

- The principal ***goal*** of the LSST Sensor Development Program is to arrive at ***a viable production-ready sensor prototype***, in one or both device technologies, ***before the start of the LSST construction, presently set for Jan 2009***.The plan to achieve this goal is described concisely in the following:

- The device technologies being developed are the next generation of CCDs with deep overdepleted substrate and segmented readout, and the hybrid PIN-CMOS. The program has two phases:

- ***Sensor Technology Study Contracts*** (***Phase II, 1 year***), and,
- ***Production-Ready Prototype Development Contracts*** (***Phase III, 2 years***).

- Phase I, a testing program to evaluate the state of presently available devices has been completed. These ***Sensor Technology Study Contracts*** will address specific technology issues, where most of the technology required to satisfy LSST sensor requirements may exist, but a specific issue needs to be addressed in order to provide a complete technology base for the subsequent prototype development in Phase III.

- Phase II shall produce test devices with all essential characteristics for LSST (QE, PSF, read noise, readout time), but may be in a smaller format than the required 4kx4k.

- Phase III shall result in production-ready prototypes

Milestones

Date	Milestone
June 1, 2005	Call for Study Proposals
July 15, 2005 Aug. 8, 2005	Due Date for Study proposals and vendor selection Proposal evaluation completed, recommendations to LSST management
September 1, 2005	***Award Study Contracts***
May 2006	RFP for Production-Ready Prototype Development
August 2006	Completion of Study Contracts
August 2006	RFP response and vendor(s) selection
October 2006	***Prototype contracts award***
October 2007	1st testable sensor according to LSST specifications
March 2008	2nd version sensors
September 2008	Delivery of tested final production-ready prototype sensors

2 months delay ...and counting

PAGE INTENTIONALLY LEFT BLANK FOR DISTRIBUTION

Phase III: Production-ready Prototype Development

- ***Vendor information package (sensor thickness study, sensor package concept; strawman CCD design, LSST requirements)*** has been distributed to CCD and PIN-CMOS vendors. Exchange of information with vendors has started, and will be completed in 07/05. Phase II, ***Study contracts*** (NSF and LSST funded) will be issued - ***Sept. 2005.***
- A formal ***RFP for Production-ready Prototype Development*** will be issued (by LSST Corp.), pending clarification of funding – ***May 2006***.
- ***RFP response and vendor selection: +~90 days, Aug. 2006***
- ***Criteria for vendor selection***: Should be able to produce sensors with required performance characteristics in quantity.

⇨ ***Sensor technology selection*** (CCD vs PIN-CMOS) based on overall evaluation of performance and the vendors; *it may be necessary and desirable to carry both technologies through prototype development.*

- ***Award vendor contract(s): +~60 days → Oct. 2006.***
- ***Contract tracking:*** Quarterly Reports, Reviews every six months.
- ***First testable silicon*** in final device format (4kx4k): +***~12 months*** after issuing R&D contracts. ***Evaluation*** of testable silicon - several months.
- ***Iterate design***, produce 2nd version silicon -- ***+~4 months***.
- ***Tested prototype delivery: ~24 months*** after issuing R&D contracts, ***Sept. 2008.***
- ***Test devices will be provided for evaluation on telescope(s). Additional funding (from other sources) may be needed to equip a sector ("raft") with 3x3 x 4kx4k sensors.***

Beware of incremental delays!