PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

Tilman Rohe

Sensors Review and Ordering

Experience with present sensors

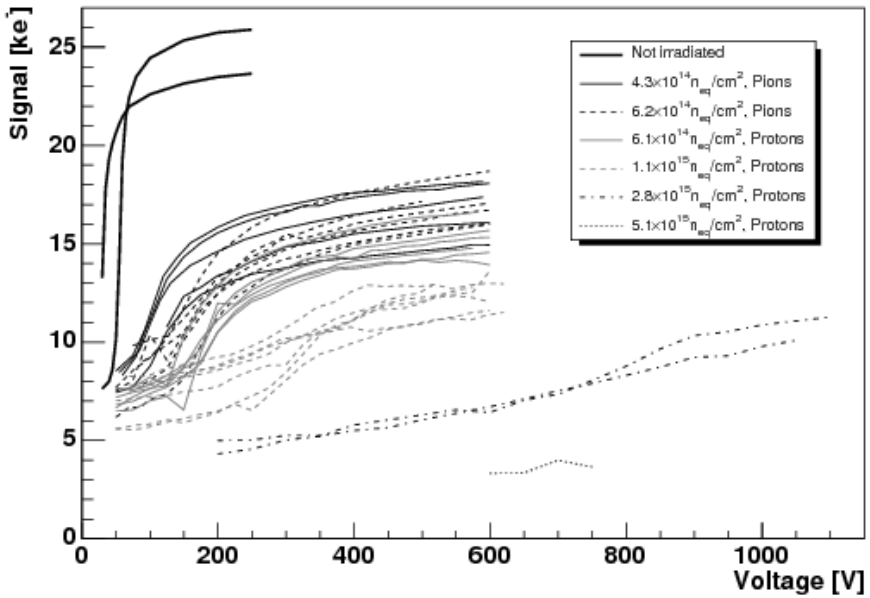
CMS

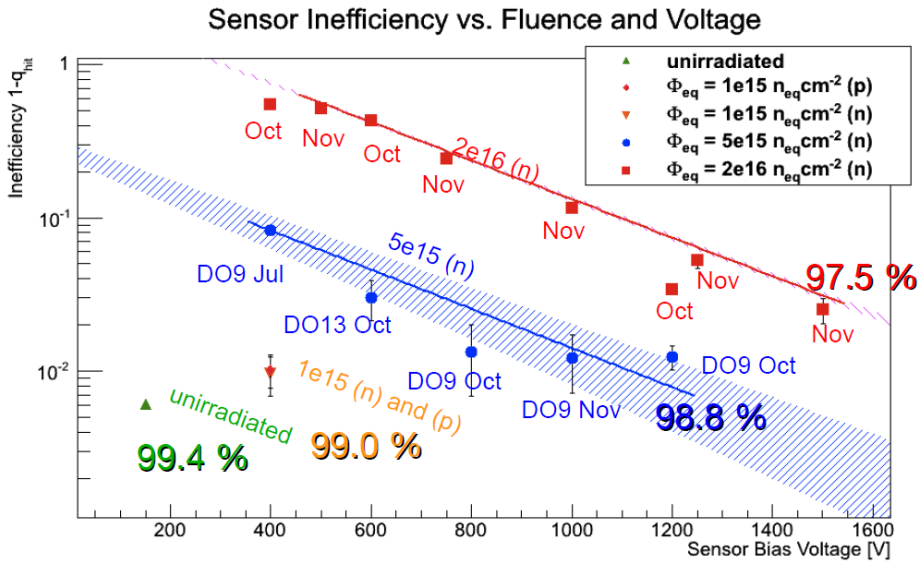
- Sensors are used for the present BPIX.
- Performance fully satisfactory
- Radiation level is still low but above the point of space charge sign ("type") inversion

Radiation hardness studies

- Up to ~1.2 × $10^{15}N_{eq}/cm^{-2}$:
  - Several test beam studies in the years 2002-06
  - Including tilt angle, B-field, and threshold
  - Summarized in NIM A 583 (2008) 25-41
- Higher fluences up to ~3 × $10^{15}N_{eq}/cm^{-2}$
  - Source tests. Dac settings and trimming procedure not 100% settled
- Fluences up to ~5 × $10^{15}N_{eq}/cm^{-2}$
  - ATLAS IBL (same sensor concept and vendor)

Signal height and detection efficiency fully sufficient for the targeted radiation level of 1.5 × $10^{15}N_{eq}/cm^{-2}$ (~250fb^{-1} in layer 1 at 3cm)





[G. Troska, TU Dortmund, PhD thesis 2012]

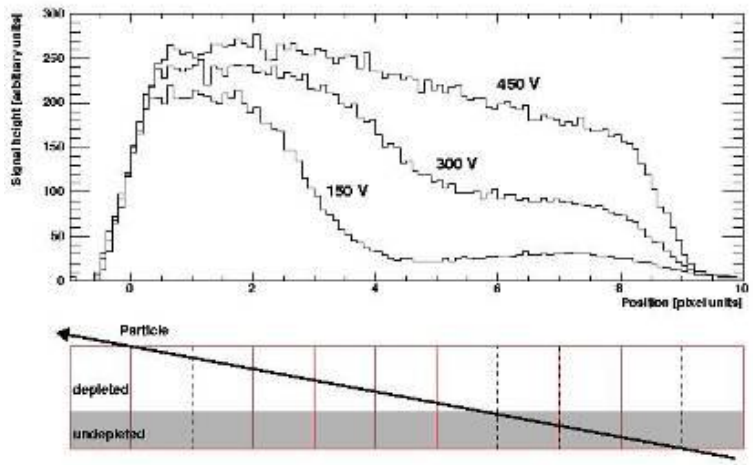
Degradation of spatial resolution

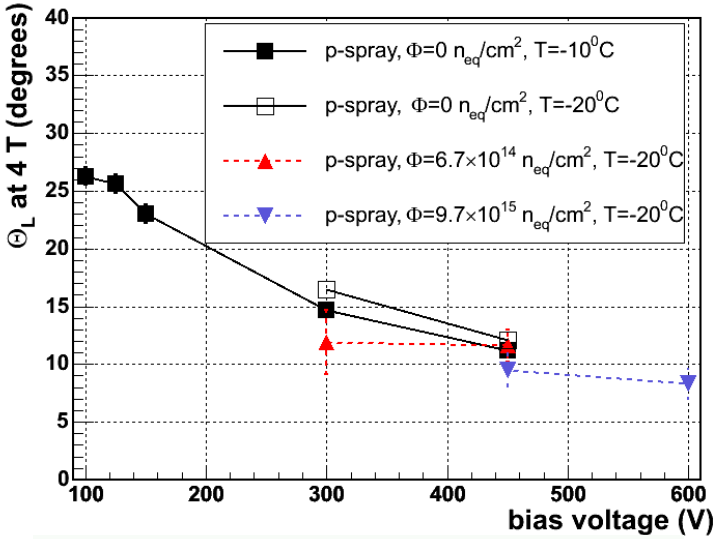
Perpendicular to the beam axis

- Lorentz angle is reduced by higher bias voltage
- Process is slow and steady
- **Well understood and measured since many years**
- **No way to prevent this (only smaller pitch)**

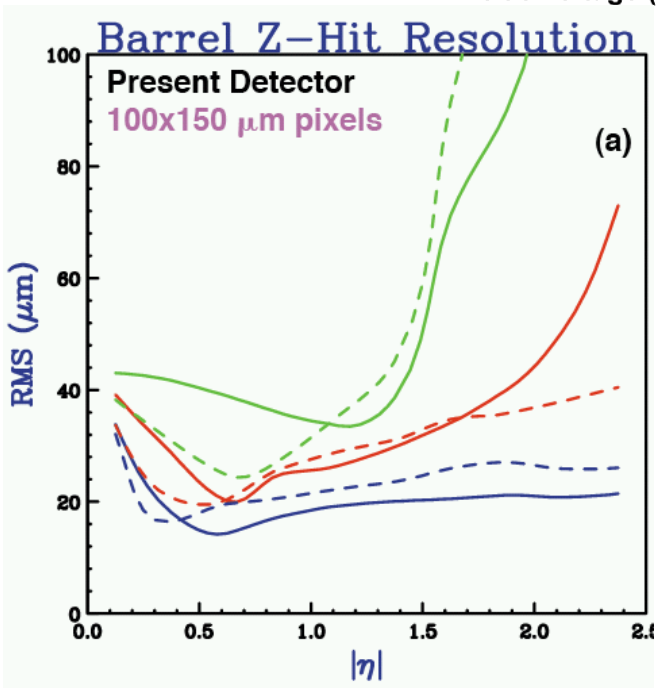
Along beam axis

- In irradiated samples the shape of cluster has to be taken into account “template algorithm”)
- If fluence is too high/signal too low:
  - fluctuations might lead to “hole” in the clusters
  - present software cannot “glue” to clusters together
  - large errors in position determination
  - **Only measure are lower thresholds (new digital ROC)**
- **Presently the operational limit of the detector**





A. Dorokhov NIM A530 (2004) 71-76

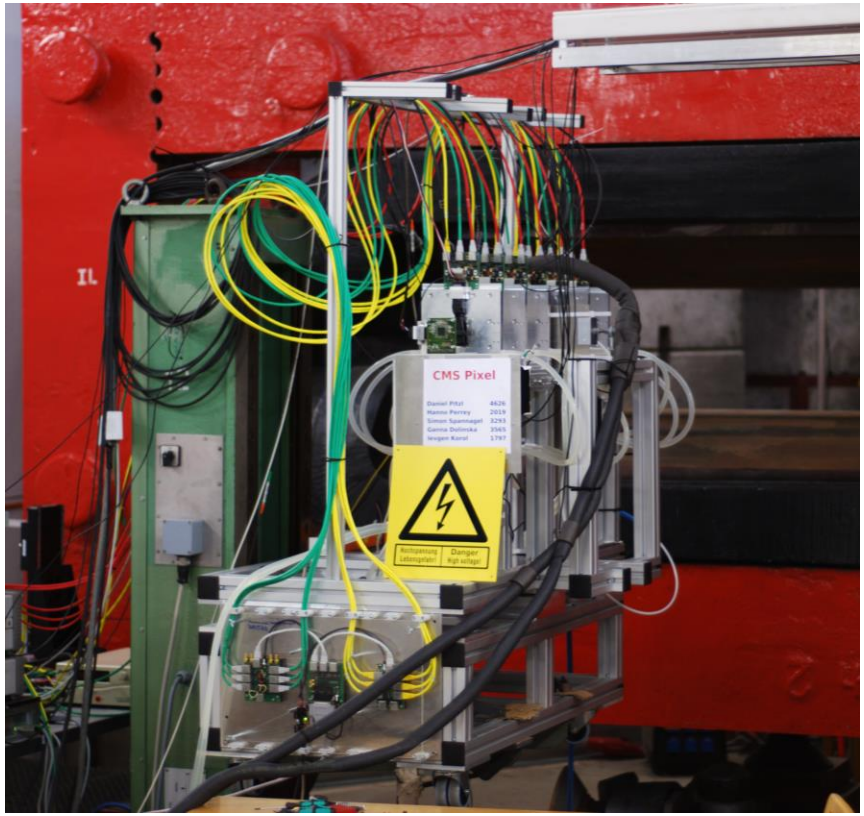


[Morris Swartz, JHU, taken from the draft TDR]

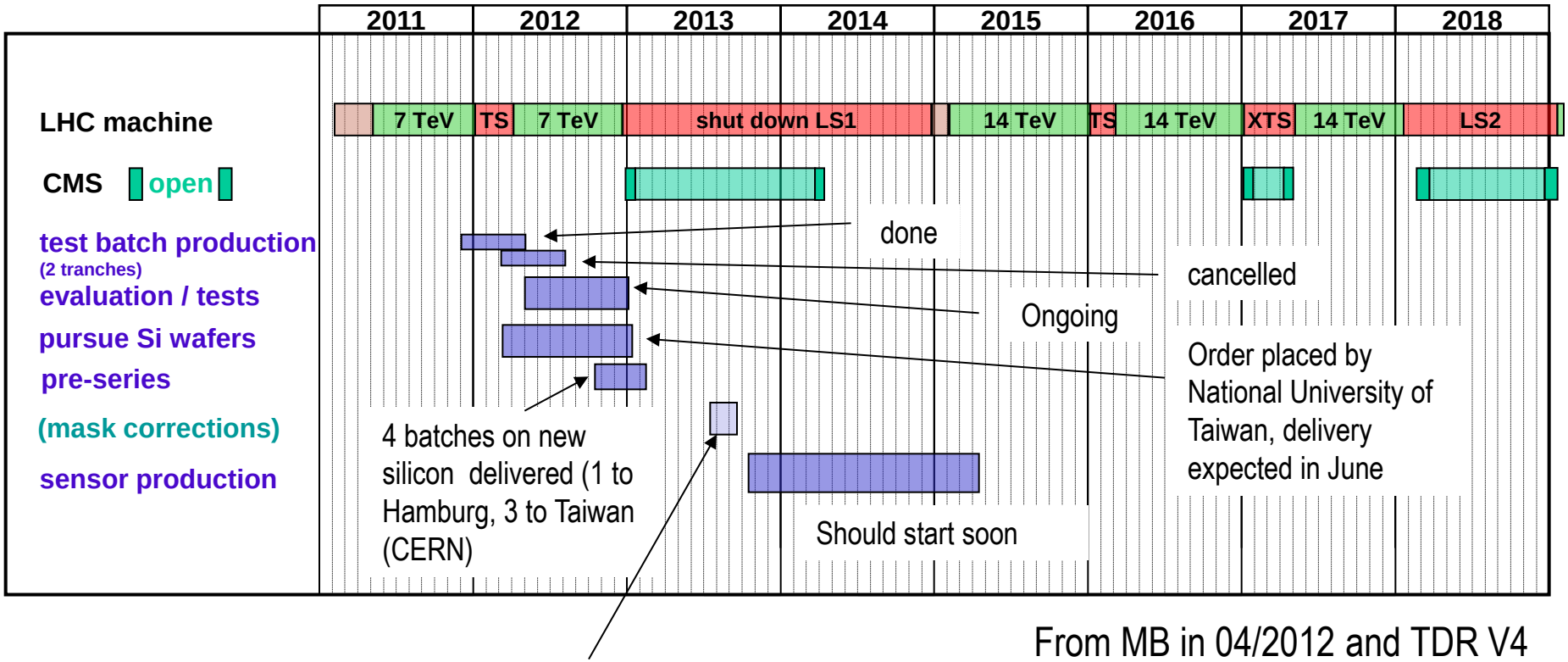
Present activities to characterize degradation

Irradiation in 2012 at KIT

- Several samples were irradiated to **$1.5 \times 10^{15} N_{eq}/cm^{-2}$ ($250 fb^{-1}$)** and $3 \times 10^{15} N_{eq}/cm^{-2}$ ($500 fb^{-1}$)
- Samples were tested in a DESY-testbeam end of March
  - Activity was performed by ETHZ (Rossini, Hits) and Santander (F. Munoz), special thanks to Daniel
- **Good data taken for $1.5 \times 10^{15} N_{eq}/cm^{-2}$**
  - Different bias (300V-1000V)
  - Angle 0 and 80 degree
  - Thresholds 40, 60, 80 (in Vcal units, digital ROC will allow for lower thresholds)
- Data for higher fluences (and 3D sensors) was taken, but might have timing issues
- Analysis of data just started (M. Rossini)



Schedule for sensor production



From MB in 04/2012 and TDR V4

Layout of the sensors “frozen” (unchanged compared to the present).

Different size of passivation openings depending on bump vendor (done)

No wishes for special alignment structures addressed to me

- Present BPIX sensors suitable for Phase I upgrade
- Exact characterization of samples irradiated to 1.5E15 N_{eq}/cm^2 (250 fb^{-1}) ongoing
  - Data taken at test beam in Hamburg in March
- Quality of Topsil silicon and polishing is verified (4 batches)
- It is time to place the 1st production order

Barrel sensor concept (n-in-n)

Collect electrons (n-side readout)

- Trapping, Lorentz angle but n-side isolation

Avoid problems in module design

- N-Substrate → double sided processing
- All sensor edges on ground potential

Pixel cell layout

- Moderated p-spray with bias grid (insensitive area)
- Small gaps, homogenous drift field, higher C ~ 80fF

Wafer

- FZ (plus Oxygen diffusion) <111>
- Phosphorous doped (n-type), 2-5 kΩcm
  - Present BPIX from single Wacker crystal
  - TOPSIL crystal (~1100 Wafer) ordered

Module

- IV curve is very sensitive and a good indicator of device quality
- I(V=150V) < 2 µA (typical value ~1µA)
- Slope I(V=150V)/I(V=100V) < 2
- I(V=150) should be stable in time

Test structures (measured only if there is a "reason")

- Diode: CV → Vdepl → ρ in specs
- $V_{punch\text{-}through}$ > 3V
- Sheet resistance of n^+ and p^+ < 500 Ω/sqr