Hamburg University CMS Group: Hardware Activities Georg Steinbrück

Visit of CMS Management in Hamburg
Feb 12/13, 2007

The Hamburg University Group

Robert Klanner, Peter Schleper,

Georg Steinbrück (staff scientist), Hartmut Stadie (1.3.2007), Doris Eckstein (1.7.2007)

Christian Autermann, Gero Flucke, Christian Sander, Roger Wolf (postdocs)

Florian Bechtel, Erik Butz, Markus Stoye (PhD students)

Alexander Clahes, Jula Dräger, Sebastian Fricke, Torben Schum, Jan Thomsen (Diploma students)

Technical support: 1 additional physicist, 2 engineers + technicians

Acces to mechanical and electronics workshops + manpower

additional group members working on ZEUS

Activities/Interests of the group:

- Hardware: Silicon Tracker + pixel (future) } This talk
- Tracker Alignment
- Physics analysis: SUSY, Top, Minimum bias/underlying event→Peter Schleper's talk Tuesday
- Computing→ Florian Bechtel's talk

Overview Hardware Projects

- Contribution to CMS Detector driven by experience of the group in radiation hard silicon and building of silicon detectors (ZEUS MVD)
- Contributions to the CMS Tracker (TEC):
  - Bonding and testing of ~1000 TEC modules (G. Steinbrück)
  - Pre-mounting of AOHs on all 288 TEC petals (G. Flucke, G. Steinbrück)
  - Mounting of silicon modules on petals at the CERN PIC (G. Flucke)
  - Characterization of CMS silicon modules in a testbeam at DESY and participation in CERN testbeam (E. Butz, M. Stoye)
  - Participation in MTCC and in MTCC analysis (E. Butz, S. Fricke), participation in „slice test" (E. Butz)
- Alignment of the CMS tracker using the MILLEPEDE algorithm (G. Flucke, M. Stoye)
- Capacity Measurement on CMS Pixel sensors (F. Bechtel)

Technical support not included above: 1 additional physicist, 2 engineers + technicians

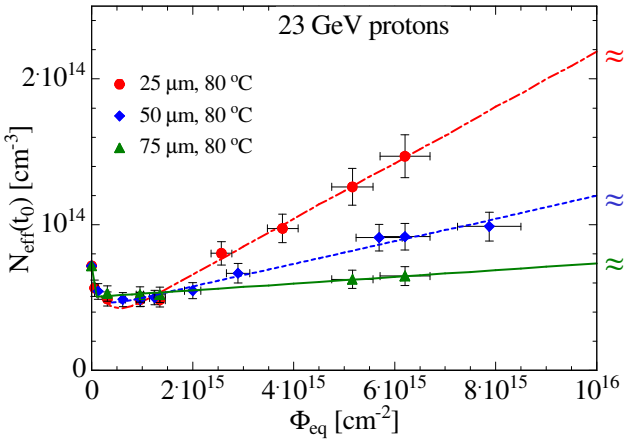
Acces to mechanical and electronics workshops + manpower

+ support from the group developing radiation hard silicon (see next slide)

Radiation Hard Silicon

- Long standing effort within the Institute
- Gunnar Lindstroem, Eckart Fretwurst + guests + students
- Basic Research on silicon as detector material
  - ·Relate macroscopic damage to microscopic defects
  - · defect engineering + predict long term performance („Hamburg model")
  - ·Optimize sensor design
- Member of CERN RD 50 collaboration

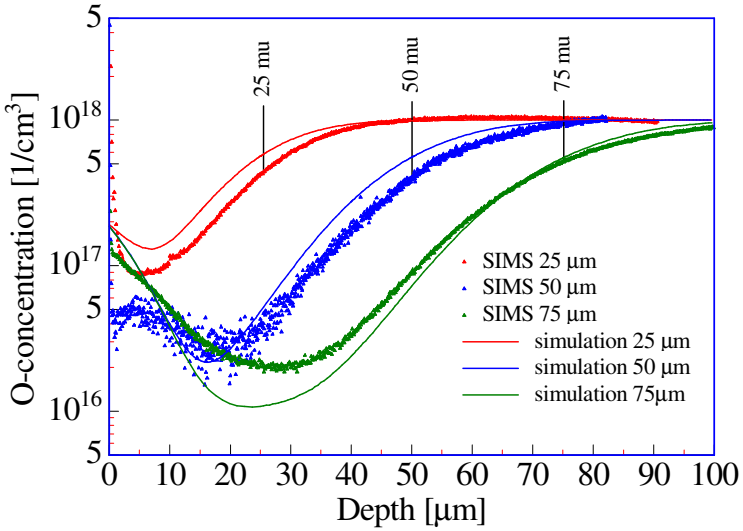
No space charge sign inversion up to $\Phi_{eq} = 10^{16}$ cm^{-2} !

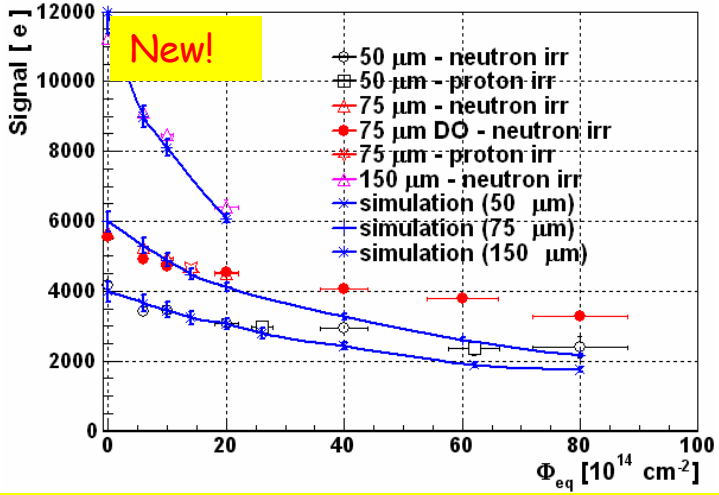


Donor creation!

Thin epitaxial Si on Sz substrate:

Diffusion of oxygen from substrate



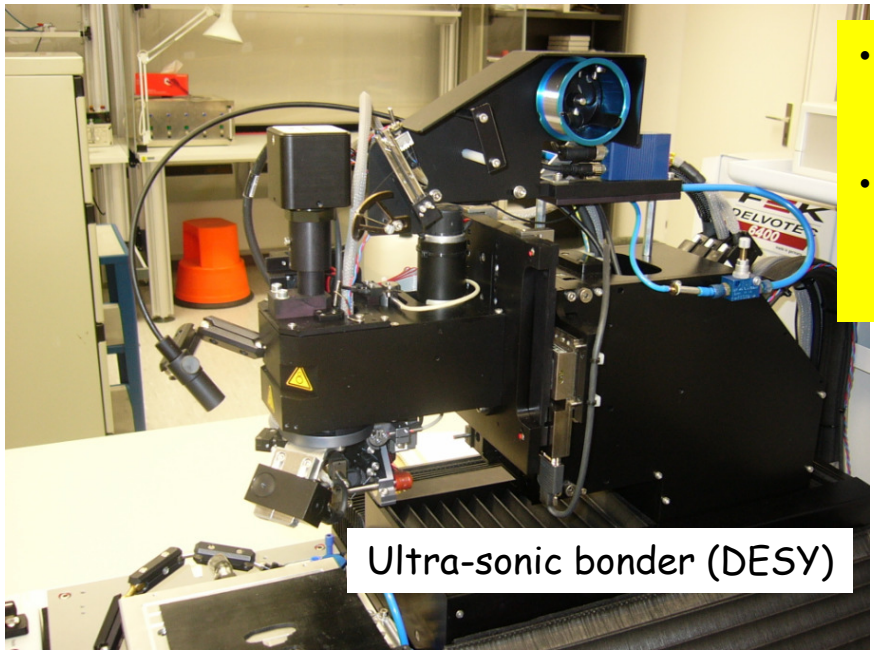


At SLHC, trapping becomes critical.

At high fluences, simulation underestimate data:

→Lower trapping probabilities than extrapolated?

CMS Tracker:
1. Bonding of Si-Modules for TEC



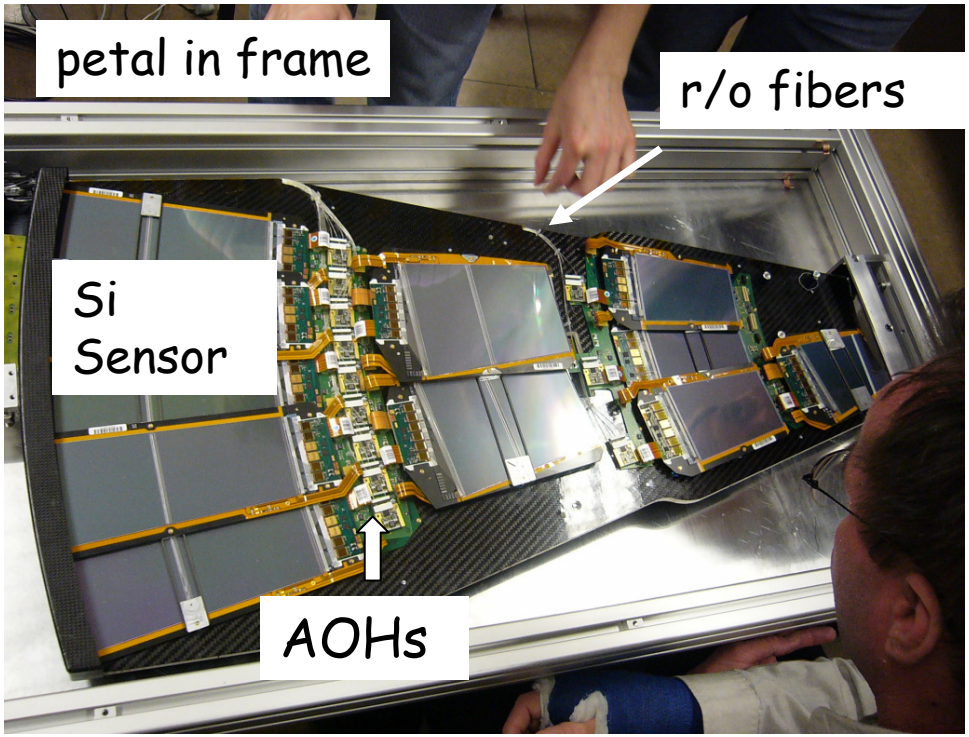
Ultra-sonic bonder (DESY)

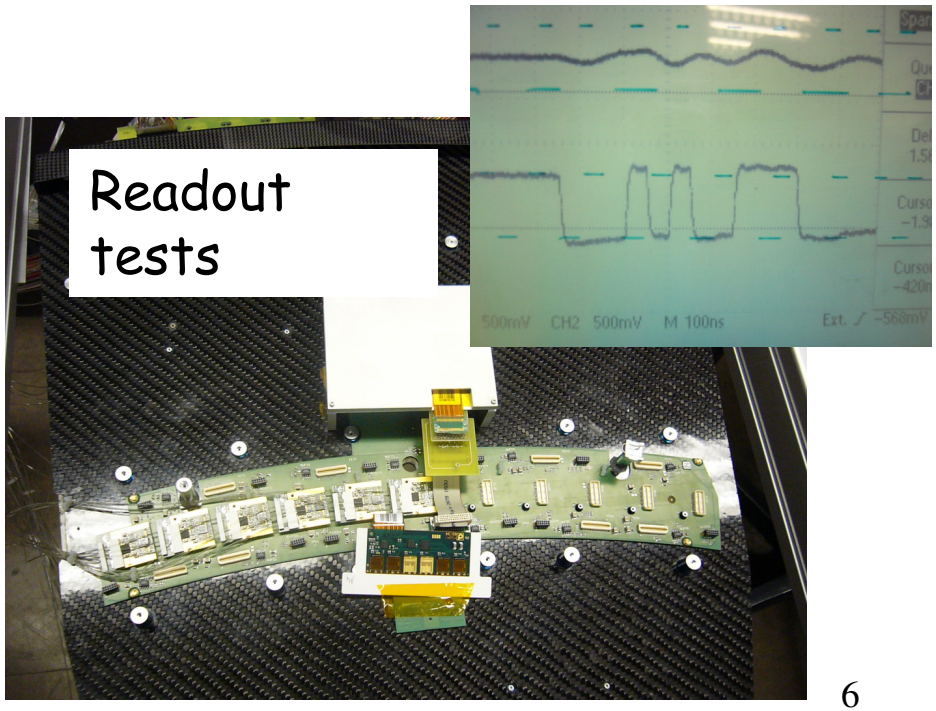
- Fine-Pitch bonding of Si-modules in ultra-sonic technique
- In close collaboration with DESY bonding-lab (ZEUS MVD): Utilizing longtime experience with HERA Det.

- Hamburg: Bonding of ~1000 modules in 3 (of 7) sensor geometries
- Qualification of bonded modules with dedicated test system (ARC)

2. Mounting of Analog Opto Hybrids (AOHs) on Petals

- Mounting of Si-modules on petals required the availibility of modules in ALL geometries.
- Interuption of module production summer 2004-summer 05
- → Used time wisely by pre-mounting and testing of AOHs on all 288 Petals in one place: Hamburg. Add. benefit: Experience in one place wrt. AOH mounting: delicate task!

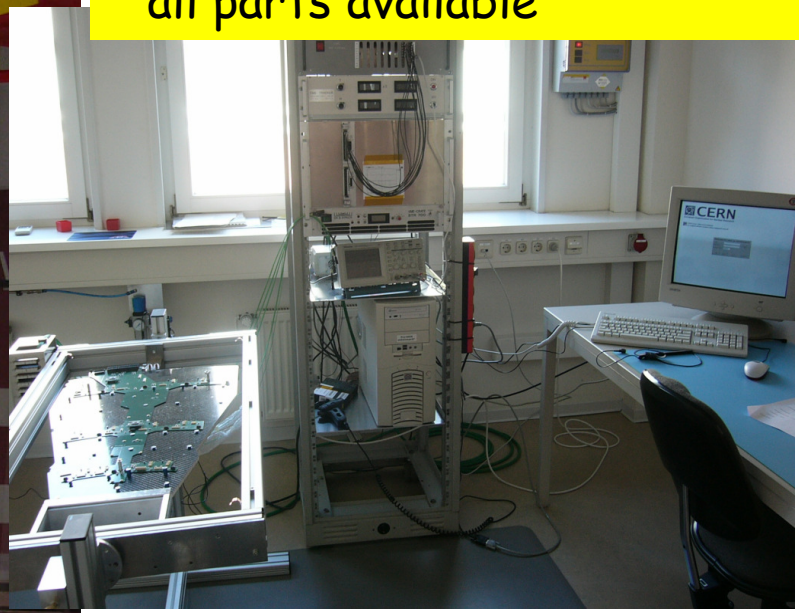




2. Mounting of Analog Opto Hybrids (AOHs) on Petals cont.

AOH mounting in Hamburg in grey-room, built for this purpose.

- AOH mounting and readout tests on two stations with 2 technicians each.
- Throughput >2 petals/day, if all parts available

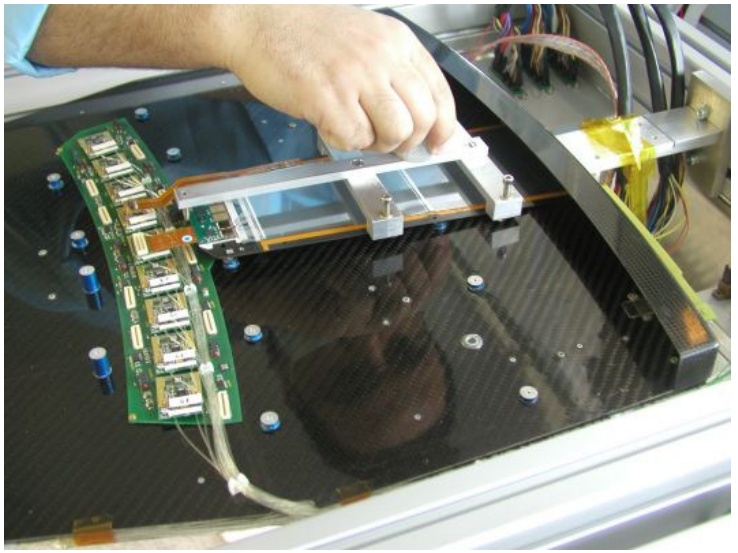


- AOH mounting March 2005-beg. 2006

CMS note in preparation

3. Module Mounting at CERN

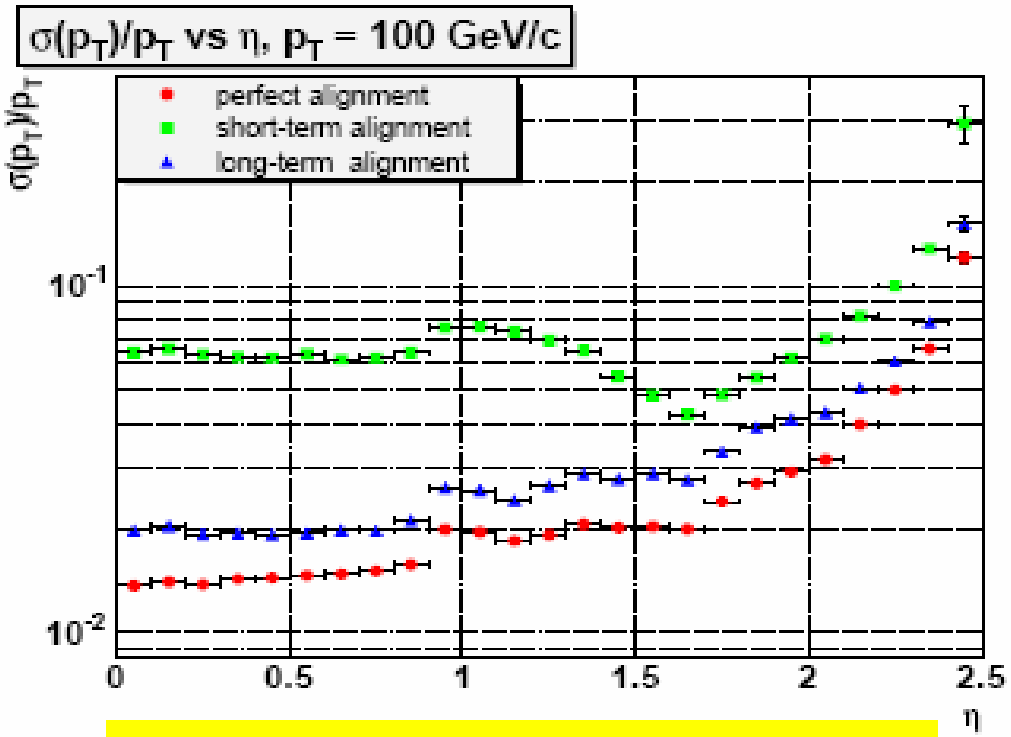
Technicians of Hamburg University mounting modules at CERN.



After end of AOH assembly:
Transferred Hamburg Petal Assembly lines to CERN for module assembly.

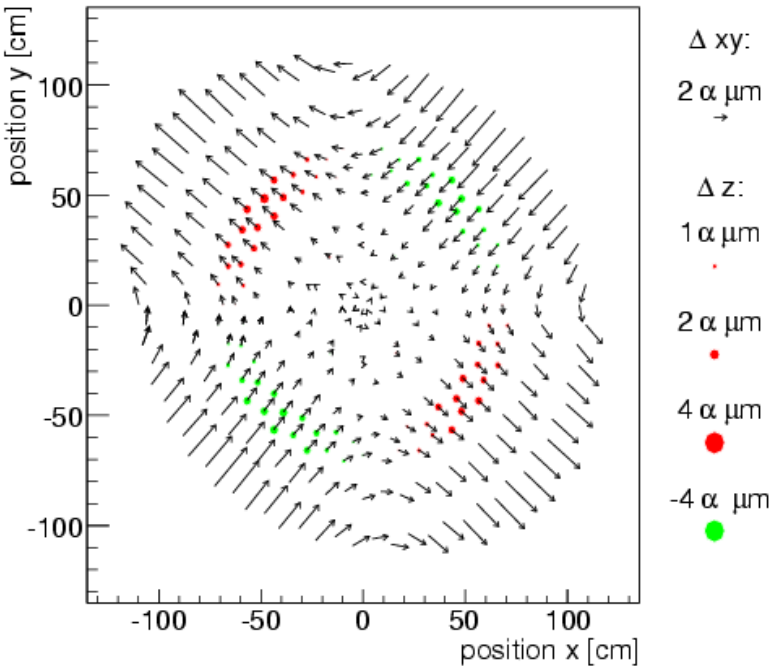
2 Hamburg Techs. went to CERN for 2 weeks/month for 6 months for module essembly,
in collaboration with Louvain

Tracker-Alignment



Impact of Tracker mis-alignment on pT resolution.

The real problems are chi-squared invariant deformations like:

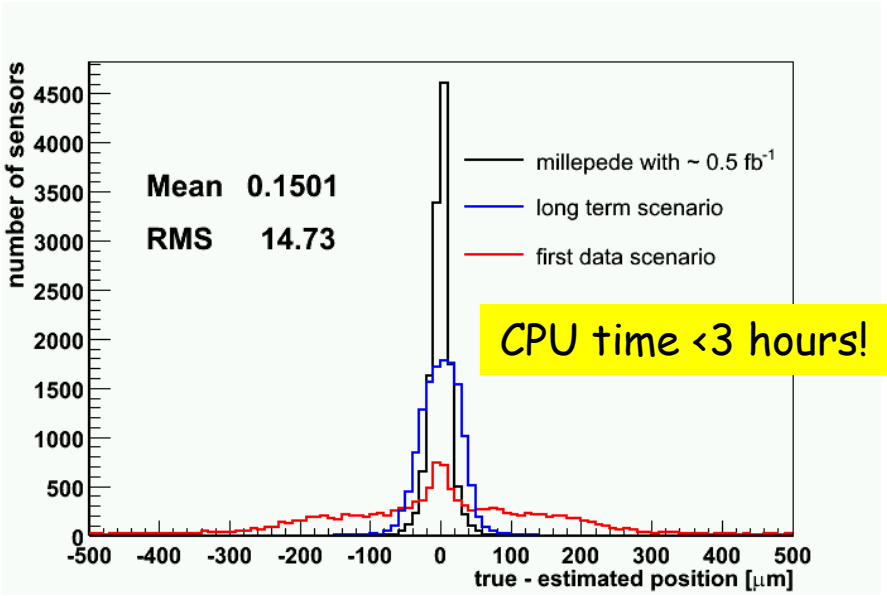


Tracker-Alignment using MILLEPEDE

MILLEPEDE is a widely used alignment package by V. Blobel (Hamburg University): H1, ZEUS, …

New version (MP II) makes it possible to tackle CMS alignment problem: ~50k alignment parameters. (new mathematical methods).

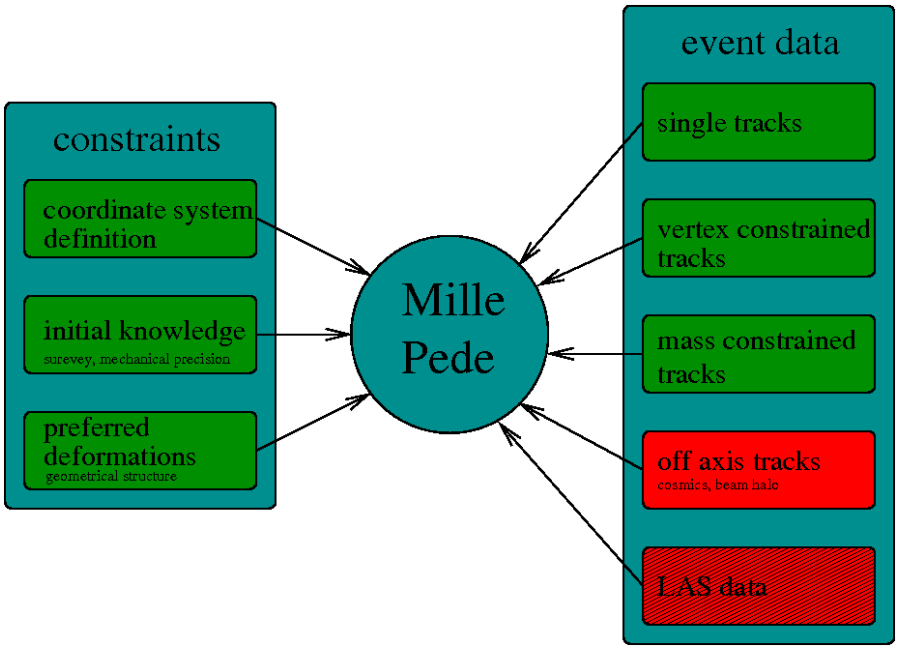
Adapted to CMS software by Markus Stoye (PhD student) and Gero Flucke (postdoc).
New DESY participation: C. Kleinwort, R. Mankel



CPU time <3 hours!

Need to utilizes all possible information.

Tools developed in HH for integration of survey info, mounting precision, preferred deformation.



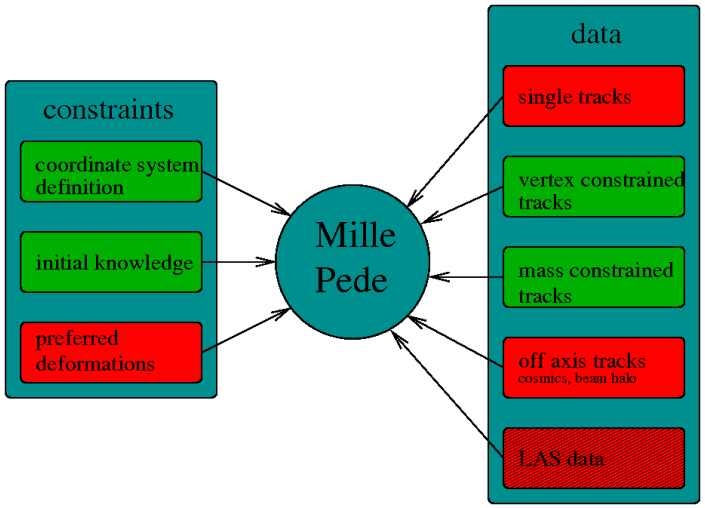
Residuals in rphi before and after alignment.

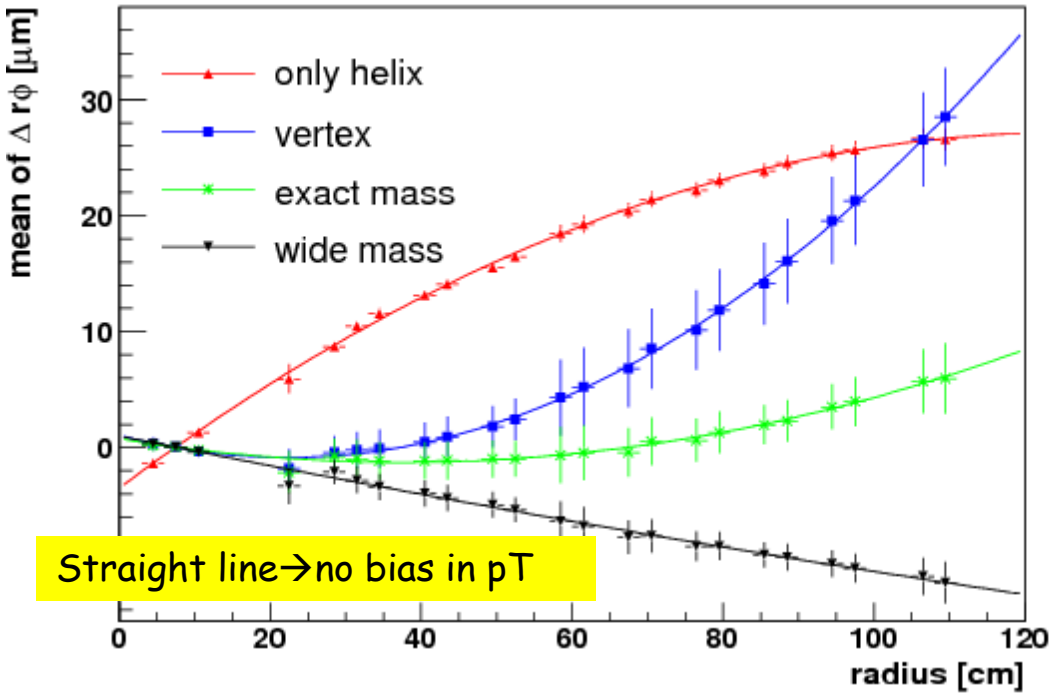
Full CMS Tracker alignment: Barrel, pixel, TEC
First converging standalone tracker alignment: No sensors kept as fixed reference!

→Milestone reached

Tracker-Alignment using MILLEPEDE

Impact of mass and vertex constraints studied.





Straight line→no bias in pT

Next step:

- Application of MPII to TIF data: Gero Flucke

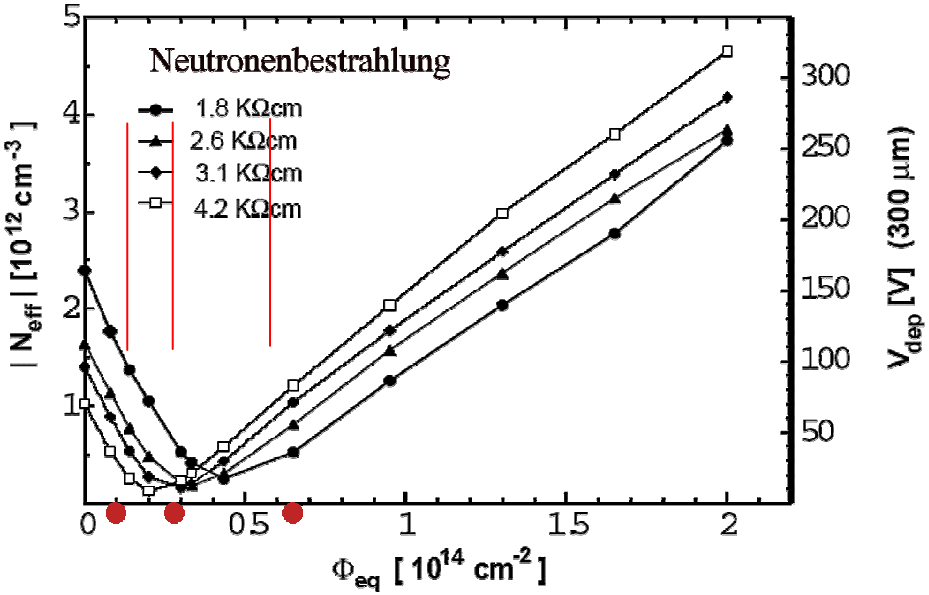
CMS note 2006/011
PhD thesis in preparation

CMS Si-Modules in DESY Testbeam

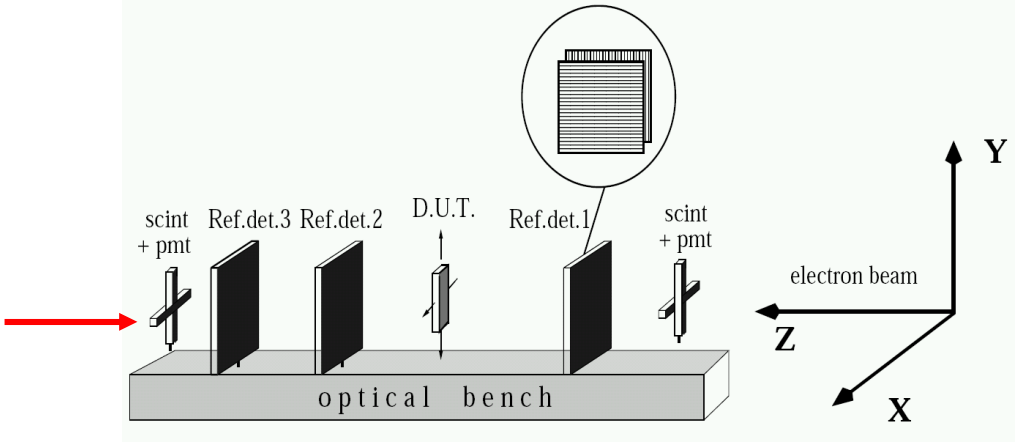
Goals:

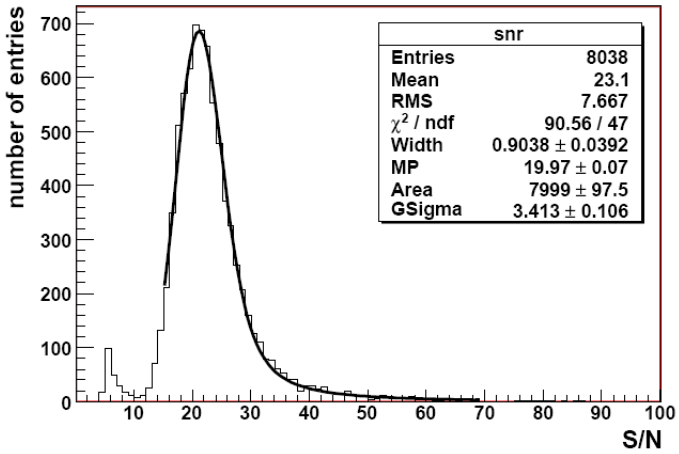
- Gain experience with CMS readout
- Characterization of irradiated modules (mainly STM, some HPK)
- S/N, spatial resolution, performance of cluster alg., spatial uniformity

Irradiation: 0 → 6.5 10^{13} 1 MeV n-eq.



Telescope-resolution
~6 µm (6 GeV) , dominated by multiple scattering

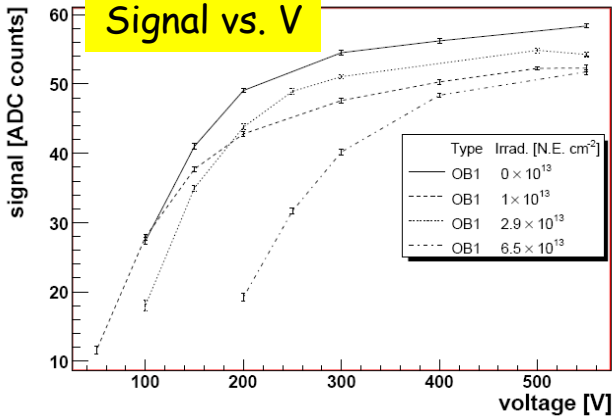




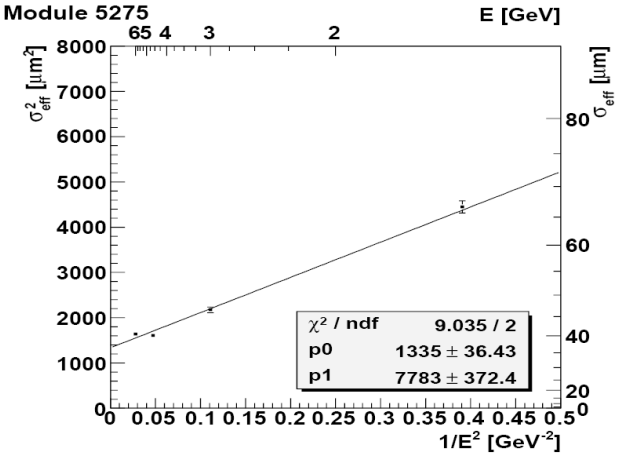
DESY Testbeam: Results

Irradiation:
0 → 6.5 10^{13}
1 MeV n-eq.

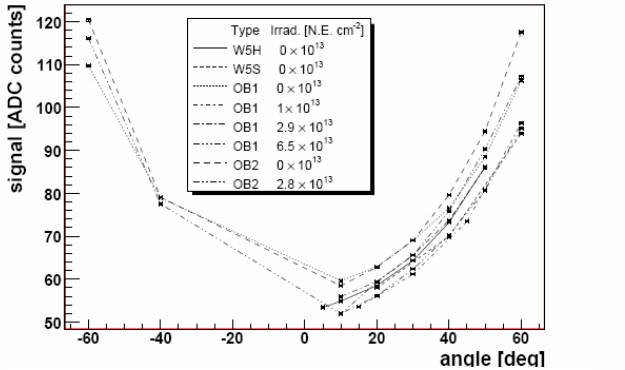
Signal vs. V



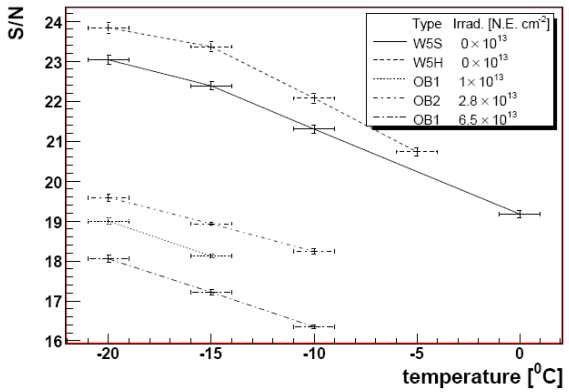
Extrapolation to infinite E gets rid of multiple scattering

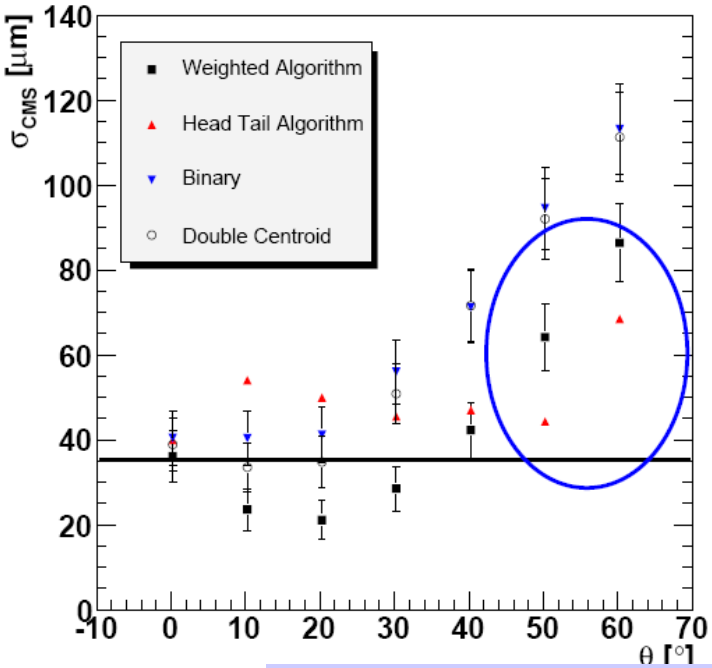


Angle scan



Temp. scan



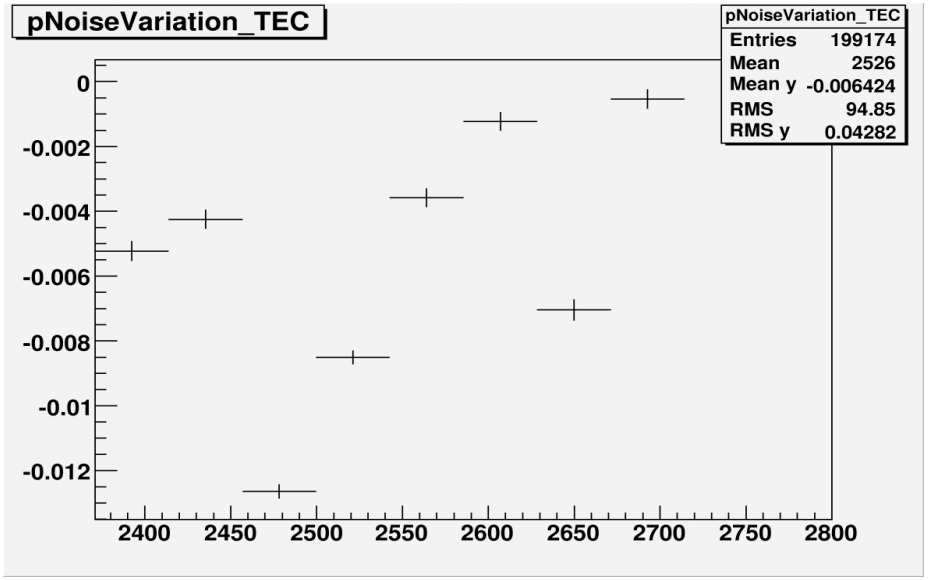


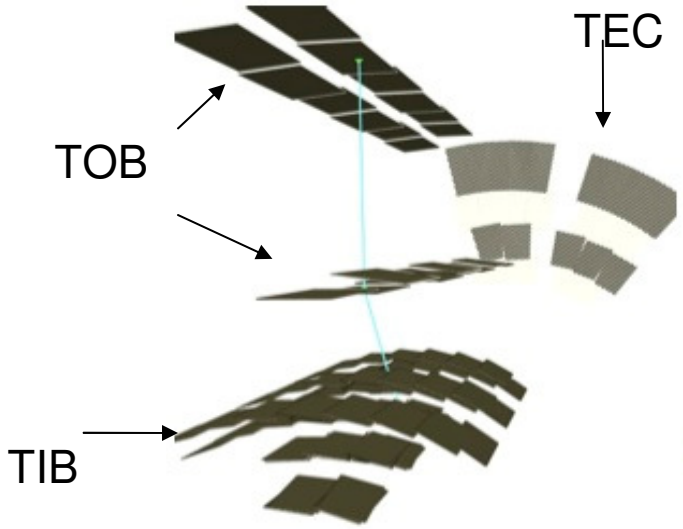
Performance of different clustering algorithms as a function of angle

CMS note and PhD thesis in preparation, 2 diploma theses

MTCC: Shifts and Data analysis

- Hamburg concentrates on TEC performance
  - In collaboration with Aachen
- Developed tools to filter TEC events
- Study of basic TEC properties like noise stability, signal/noise, etc





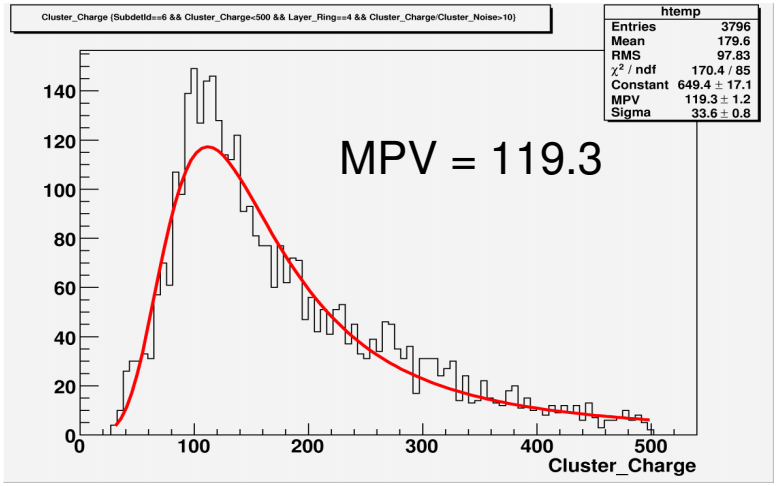
Detectors (Tracker):

- TOB: 24 modules, 4 rods
- TIB: 75 modules (L2 + L3)
- TEC: 34 modules (2 disk 9 petals)

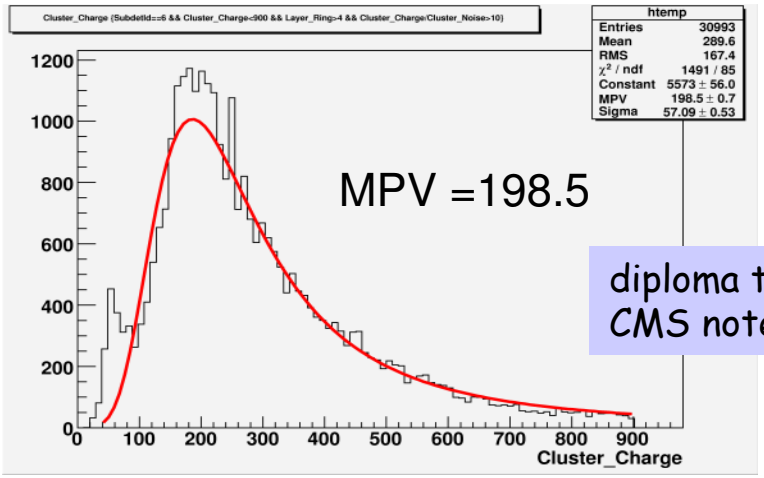
Trigger provided by muon systems: DT, CSC, RPC

MTCC Results: TEC

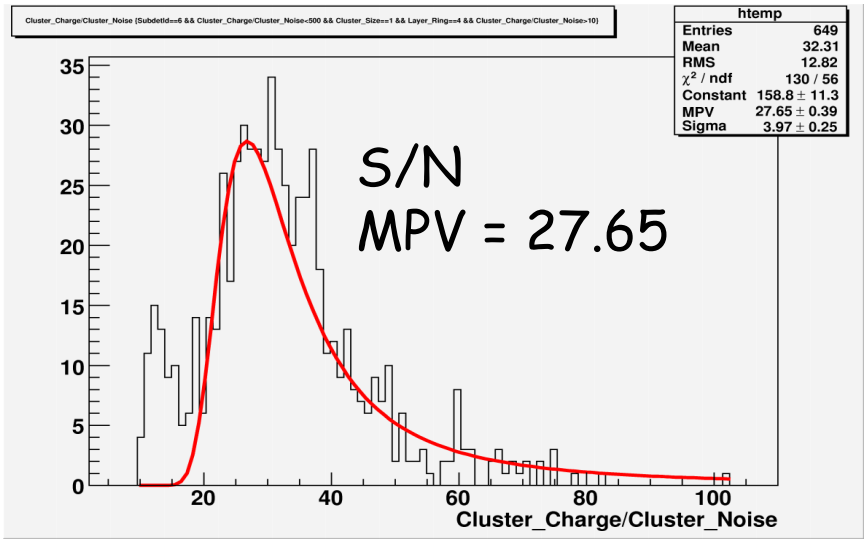
Ring 4 (320 µm Si)



Ring 5 to 7 (500 µm)



diploma thesis in preparation
CMS note in preparation



Successful participation in MTCC.

Results show that CMS Si-modules perform well in 4T field.

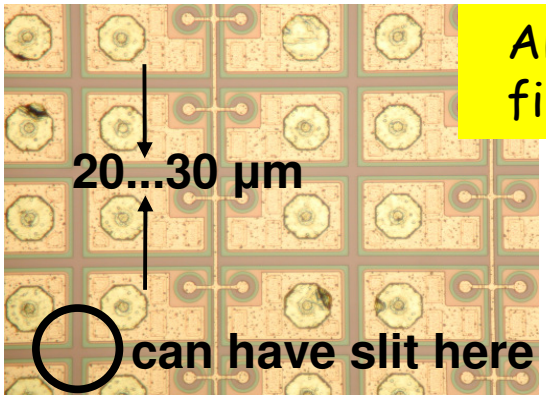
→CMS note in preparation with UHH contribution

PhD student at CERN to participate in slice test

Start Activity on CMS Pixel

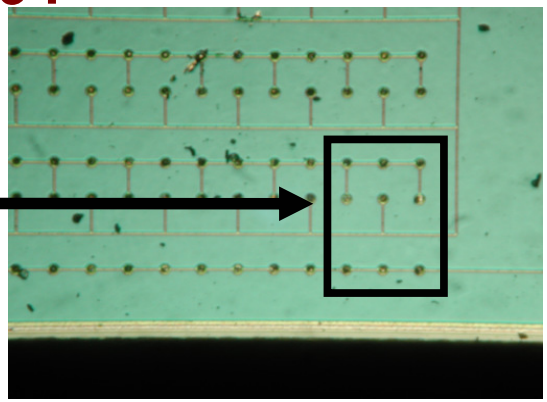
Aim: Optimize present design for radiation tolerance
first step: inter-pixel capacitance vs gap width

Pixel cell :



Readout structure :

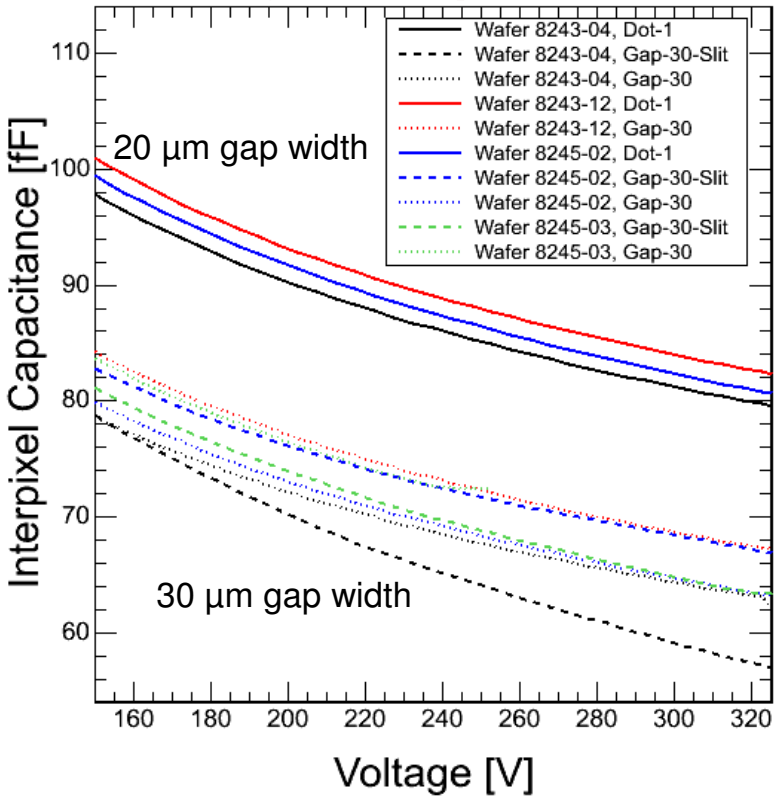
190 times this structure



Measurements done at PSI.
Challenge: Capaciatance O(100 fF)!

- **measured capacitance:**
  - $C_{measured}=\Sigma C_{inter\text{-}pixel}+C_{stray}=190*C_{inter\text{-}pixel}+C_{stray}$
- **three different sensor designs investigated:**
  - **Dot 1:** 20 µm gap width, no slit
  - **Gap 30:** 30 µm gap width, no slit
  - **Gap 30 Slit:** 30 µm gap width with slits

Design Comparison :



Capacitance curves corresponding to different gap widths clearly separable

Future Activities

- Alignment
  - New members from DESY: Claus Kleinwort, Rainer Mankel
  - Alignment with real data
  - Collaboration with other institutes
  - Strong presence at CERN
  - Extension to tracker → calorimetry
- Strip Tracker commissioning: MTCC→slice test→ …
  - 1-2 people at CERN
- Pixel Detector:
  - Discussions with R. Horisberger about participation in Pixel Upgrade (2011/12)
  - Nb. Group is also involved in development of hybrid pixel detector for the XFEL (project is in the proposal stage). Both projects would profit from each other!
  - Extension to SLHC ?
  - SLHC: Expertise in development of radiation hard silicon, sensor simulations