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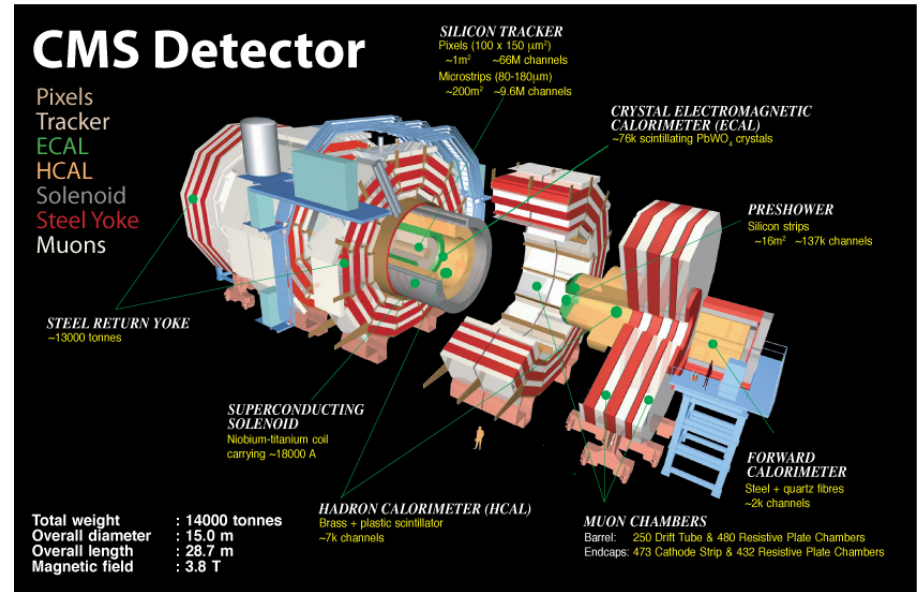
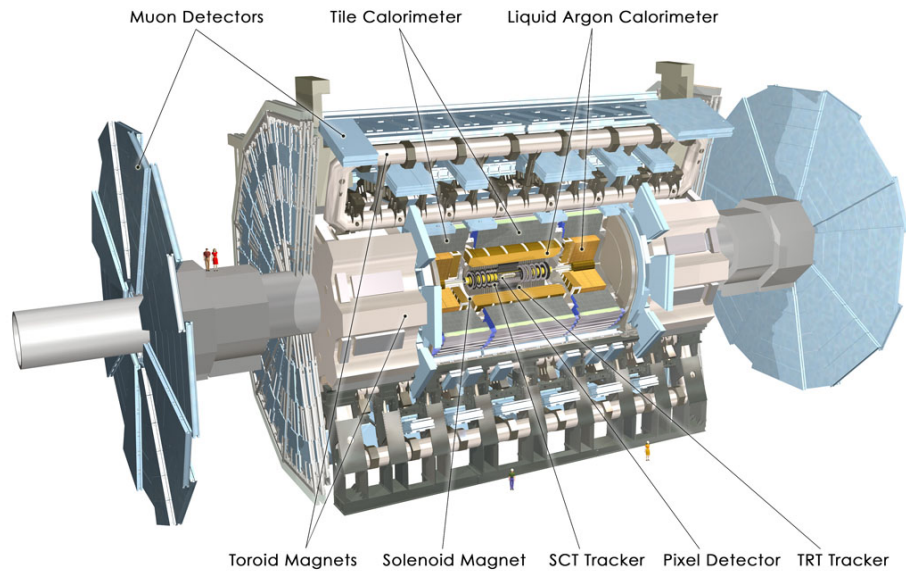
Radiation Damage in LHC detectors: summary of the session

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on behalf of the LHC Radiation Damage Working Group

LHC silicon detectors



ATLAS: Pixel Detector and SCT Tracker

Semi-Conductor Tracker: 61 m² of p-on-n (single sided), 4088 modules with 6.3M readout channels. 285 μm . Temperatures from -7^o to 6^oC

Pixels: n-on-on, 256 μm thick. ~1.7m²

Operating temperature of about -13^oC

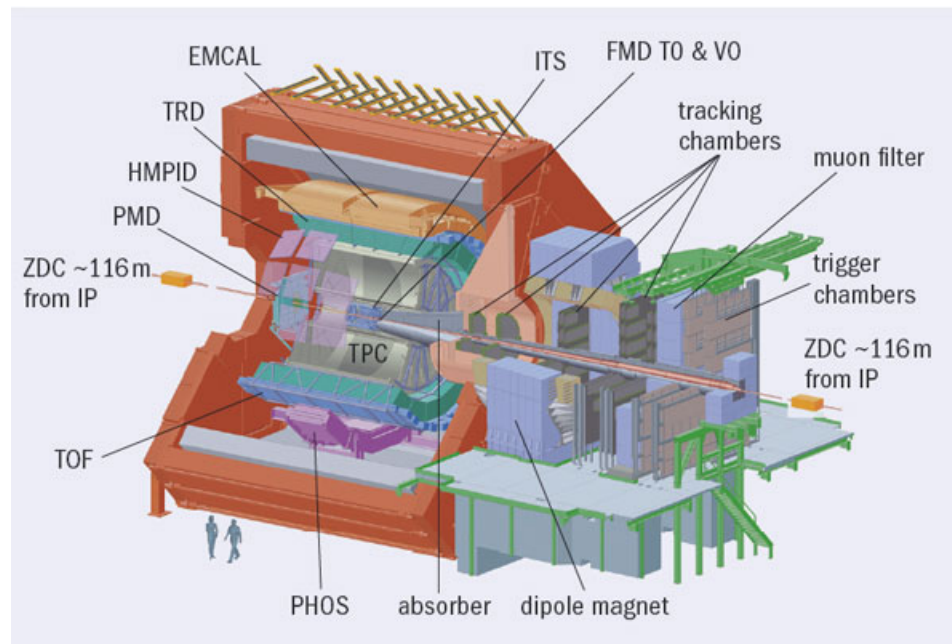
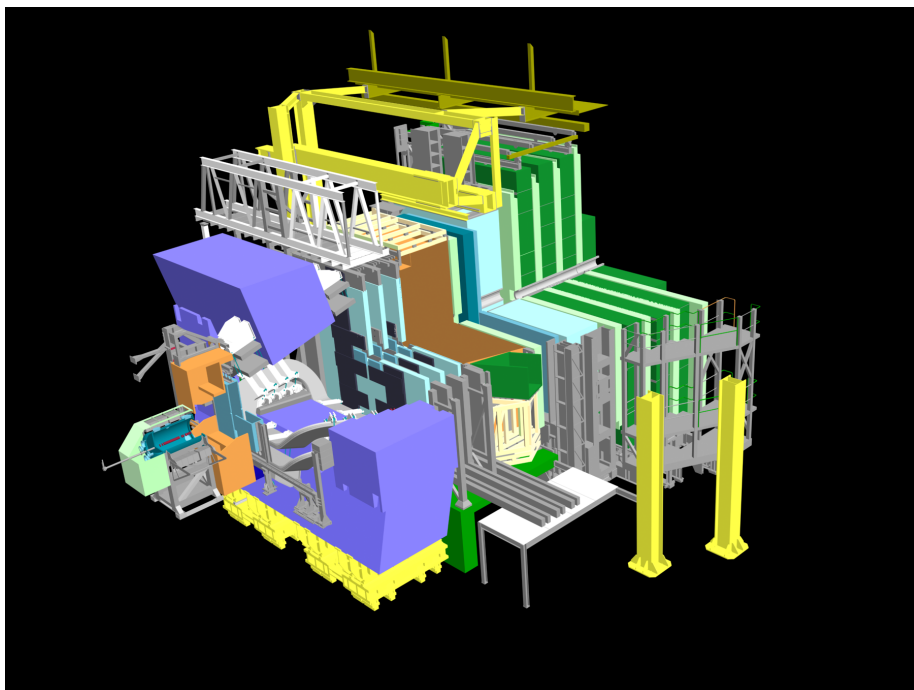
CMS Silicon Tracker: Pixels and Microstrips

Strips: 200 m² (p-on-n), ~26000 sensors, 300 and 500 μm , 300V bias voltage.

Pixels: 1.06 m² (oxygenated n-on-n), 66M pixels, 285 μm , 150V or 300V bias voltage.

Operating temperature of about +10^oC (2012)

LHC silicon detectors



LHCb: VELO (the Vertex Locator), sensors are mostly n-on-n (84) and 2 are n-on-p. $300 \mu\text{m}$ @ -8°C , oxygenated. 150V bias.

Less integrated luminosity: about 6 fb^{-1} comparing to 29.6 fb^{-1} of ATLAS and CMS.

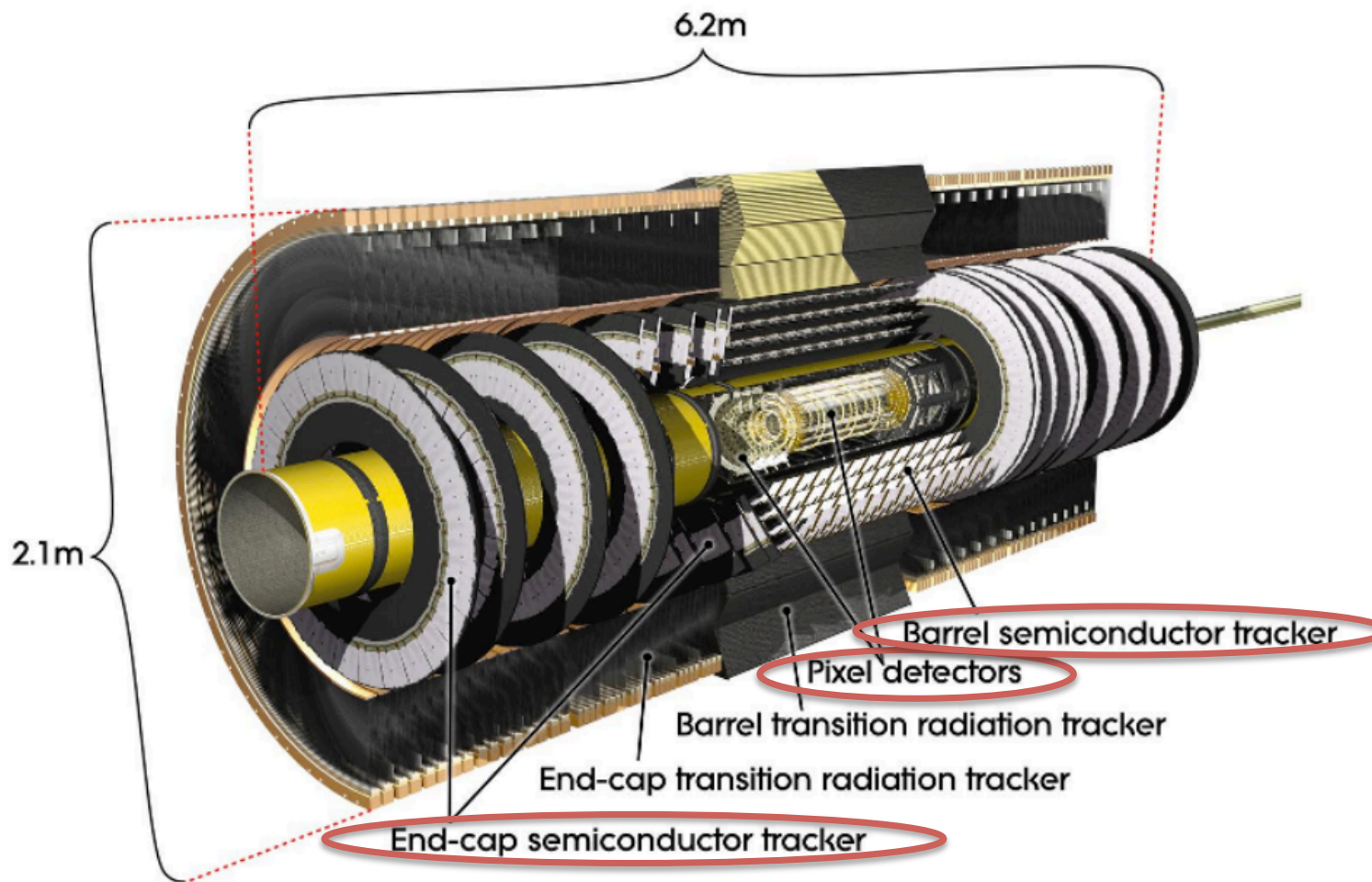
ALICE: SPD – the Silicon Pixel Detector. p-on-n, $150\text{-}200 \mu\text{m}$.

Much less integrated luminosity: hundreds of nb^{-1} for heavy ion collisions, few pb^{-1} with proton-proton collisions.

LHC inter-experiment radiation damage working group

- Set up in 2011.
- Special sessions at the RD50 workshops since 2011 (first took place at 19th workshop).
- Develop a common approach; e.g. all plots scaled to 0°C equivalent.
- Sharepoint group and mailing list:
 - <https://cern.ch/rad-damage-iewg/>
 - rad-damage-iewg@cern.ch

ATLAS Inner Detector



ATLAS ID talks on this conference:

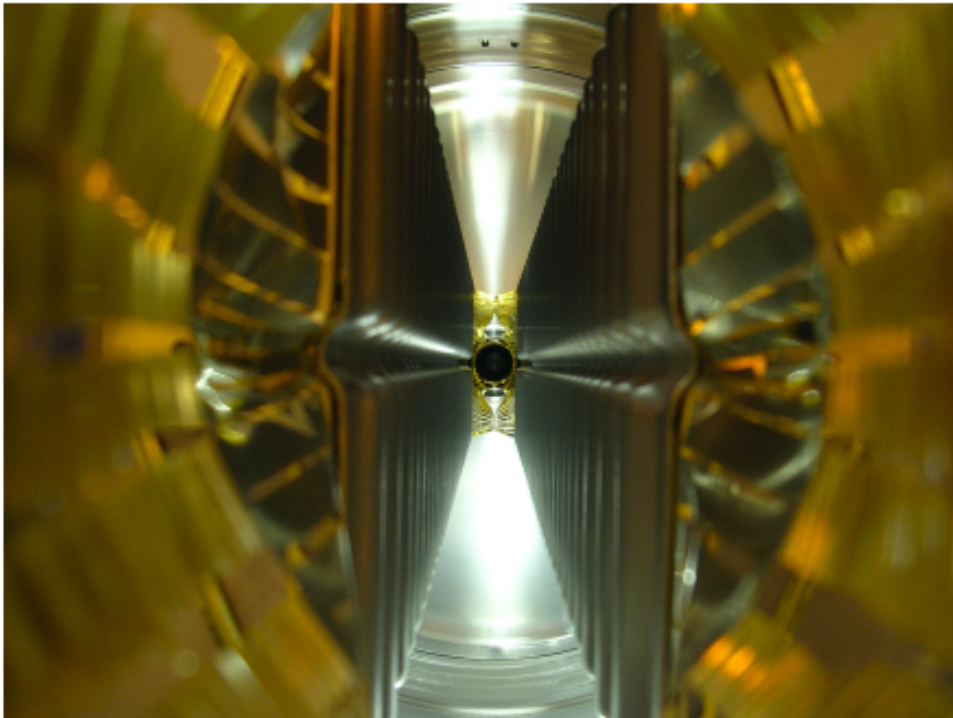
- Igor Gorelov, “Radiation Damage of the ATLAS Pixel Sensors Using Leakage Current Measurement System”
- Taka Kondo, “Status of radiation damage of the ATLAS SCT detector”

ATLAS Inner Detector

- Pixels:
 - Dedicated hardware for the leakage current measurements (HVPP4 system), $\sim 1\text{-}20\text{nA}$ precision
 - Cross-check measurements: 1) through HV supplies; 2) per-pixel measurements are possible (talk by Markus Keil, 20th RD50)
 - Good agreement with model (see Igor's talk today)
 - Depletion voltages: cross-talk (per module) and track-based depletion depth methods.
- SCT:
 - Well advanced analysis developed, SCT results have been shown at many conferences (see today's talk by Taka)
 - Nice correspondence within 20% with the Hamburg/Dortmund model for the leakage currents.

LHCb VELO

- Talk today by Zhou Xing, “Radiation damage effects in the LHCb Vertex Locator”
- Several methods of study of the radiation damage effects: leakage currents, depletion voltage, noise measurements
- No significant influence on physics performance
- Paper submitted to JINST (e-print arXiv:1302.5259 [hep-ex], CERN-LHCb-DP-2012-005)



CMS tracker

- Refer to the latest talk by Seth Zenz, “Radiation damage effects to the CMS Silicon Tracker”, <https://indico.cern.ch/getFile.py/access?contribId=22&sessionId=1&resId=0&materialId=slides&confId=200290>
- Leakage current measurements in pixels, depletion voltage measurements.
- Reasonable agreement with model.
- Work is ongoing.
- We hope to see an update at the next RD50 😊

ALICE

- SPD: the Silicon Pixel Detector (<http://aliceinfo.cern.ch/SPD/>)
- Quote from the mail from Vito Manzari:

*“Actually, I'm wondering whether a talk on the SPD would be a relevant contribution to the RD50 workshop taking into account that the radiation level in ALICE is dramatically lower than in ATLAS and CMS; indeed, at the moment we keep monitoring our electronics although there are no clear indication of degradation due to radiation. As I have seen from the RD50 web site that **next workshop will be in November this year and it will take place at CERN, we may consider to have an SPD contribution merged with the future ALICE pixel detector**, for which a substantially increase of the radiation level is expected and thus we are currently carrying on a radiation studies campaign”.*

Conclusion

- ATLAS, CMS and LHCb experiments have well-advanced studies of radiation damage in silicon detectors.
- Currently the LHC is in a long-shutdown mode, more measurements are possible with direct access to the modules.
- Inter-experiment Radiation Damage Working Group is active.
- Many thanks to all of the speakers and to people involved!