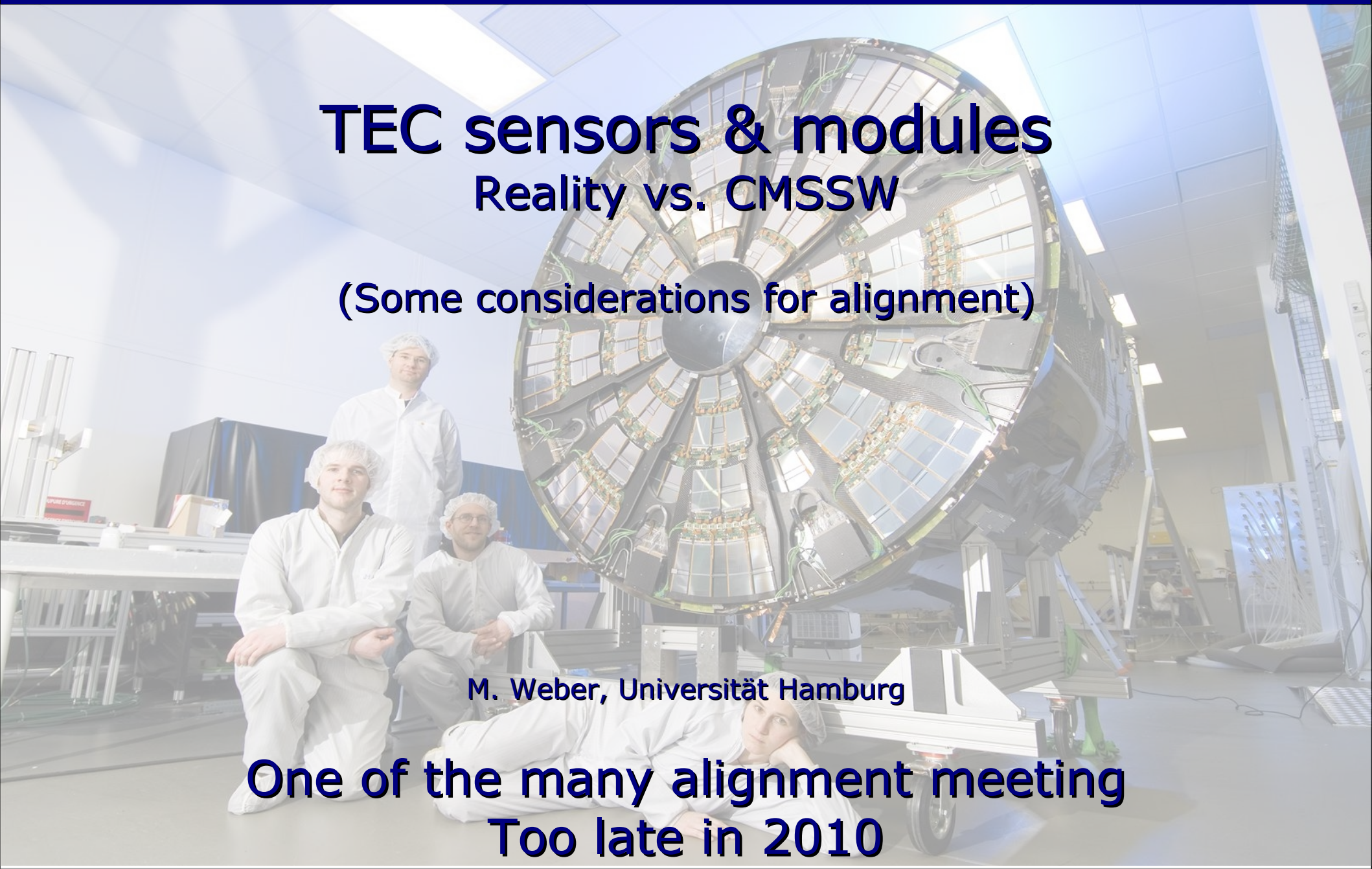
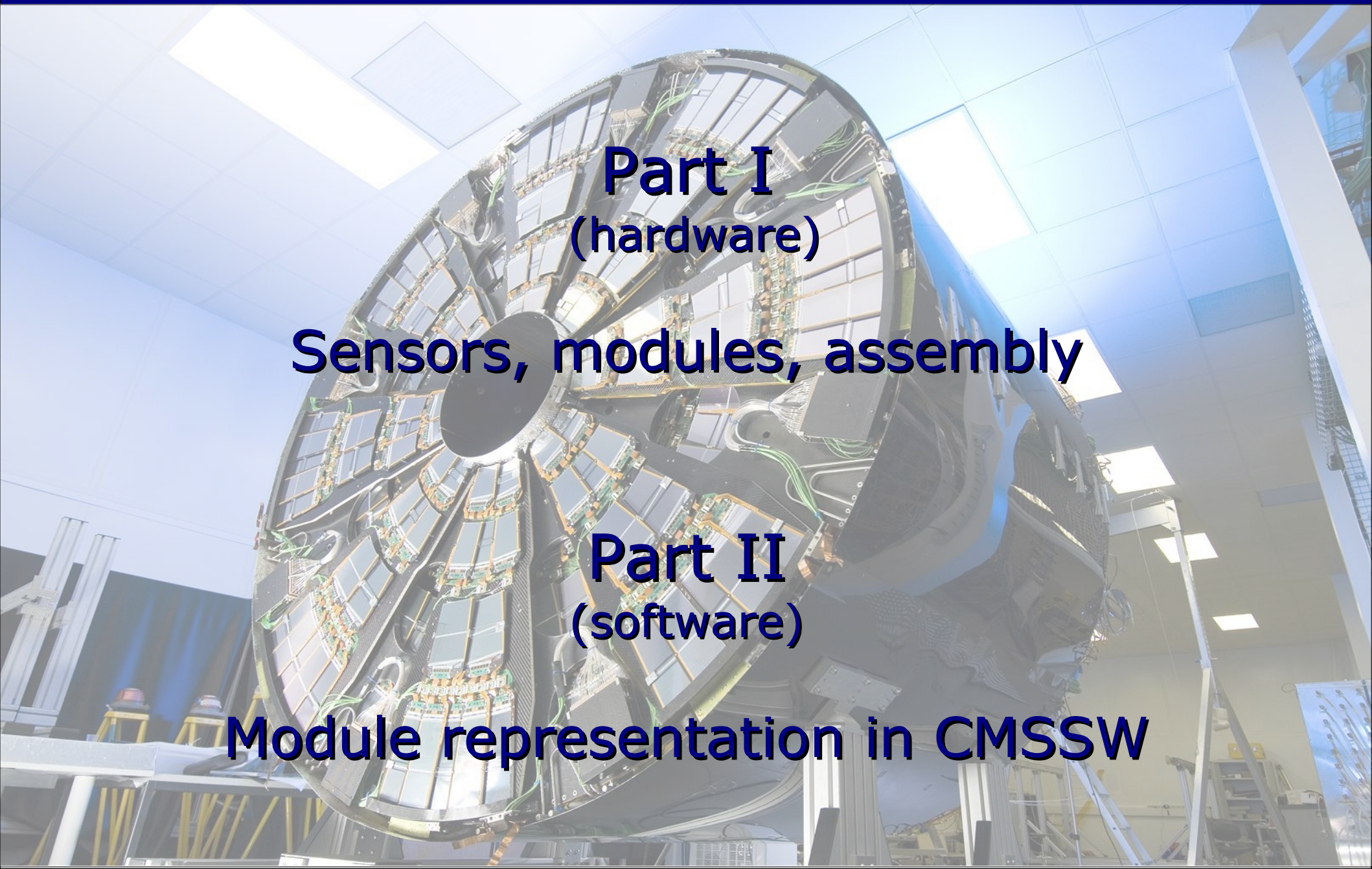


TEC sensors & modules
Reality vs. CMSSW

(Some considerations for alignment)

M. Weber, Universität Hamburg

One of the many alignment meeting
Too late in 2010



Part I
(hardware)

Sensors, modules, assembly

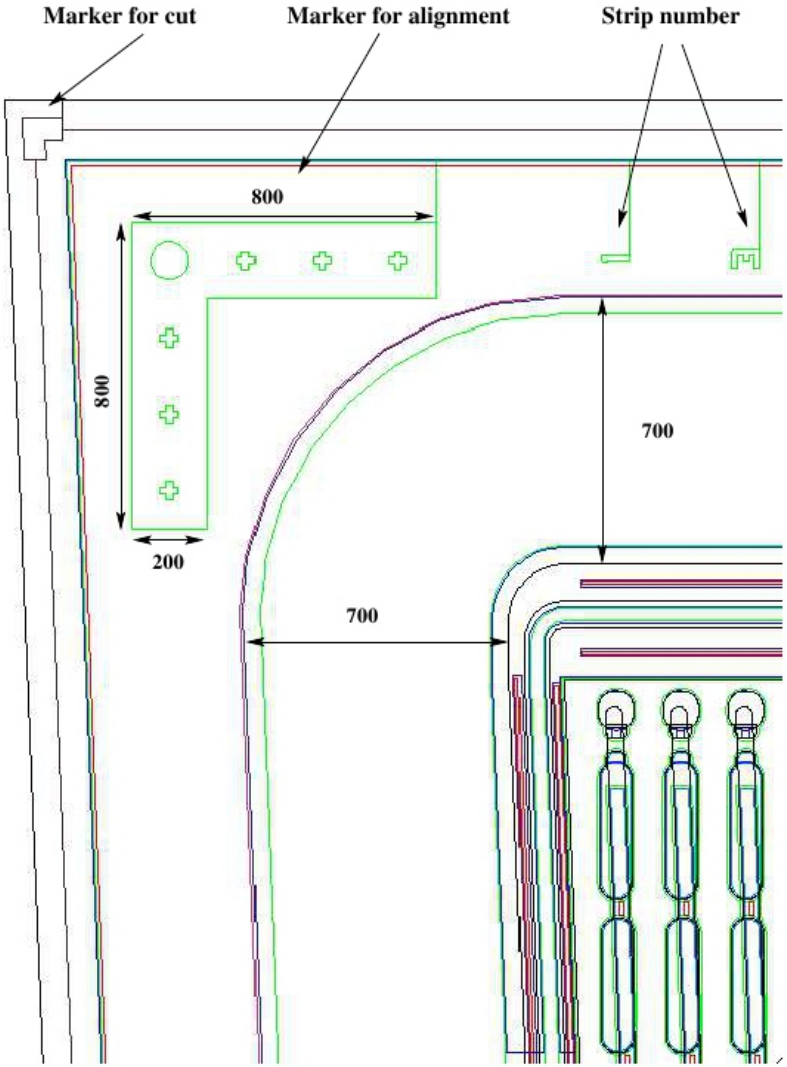
Part II
(software)

Module representation in CMSSW

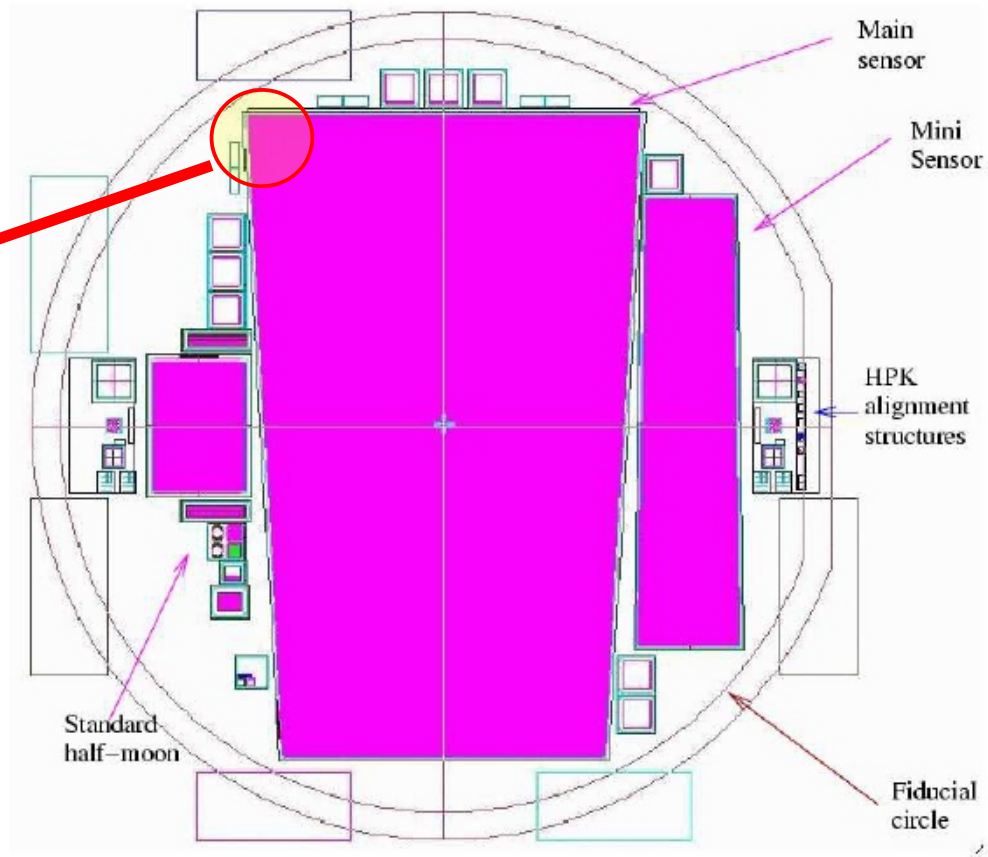
Part I

Sensors, modules, assembly

- Details can be found in CMS Note 2003/020

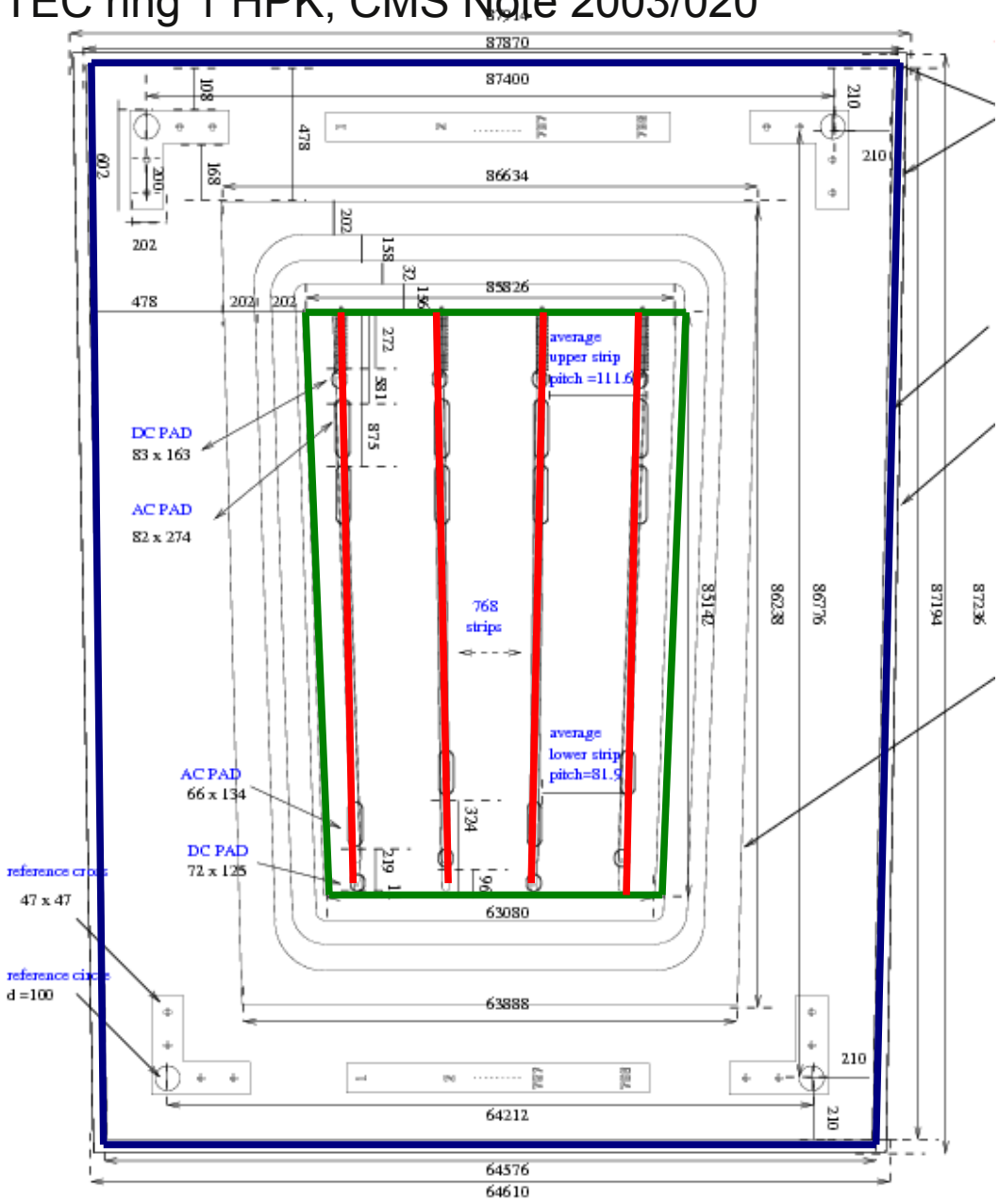


TEC Ring 4 (HPK)



TEC/TID sensor sketch (not to scale)

TEC ring 1 HPK, CMS Note 2003/020

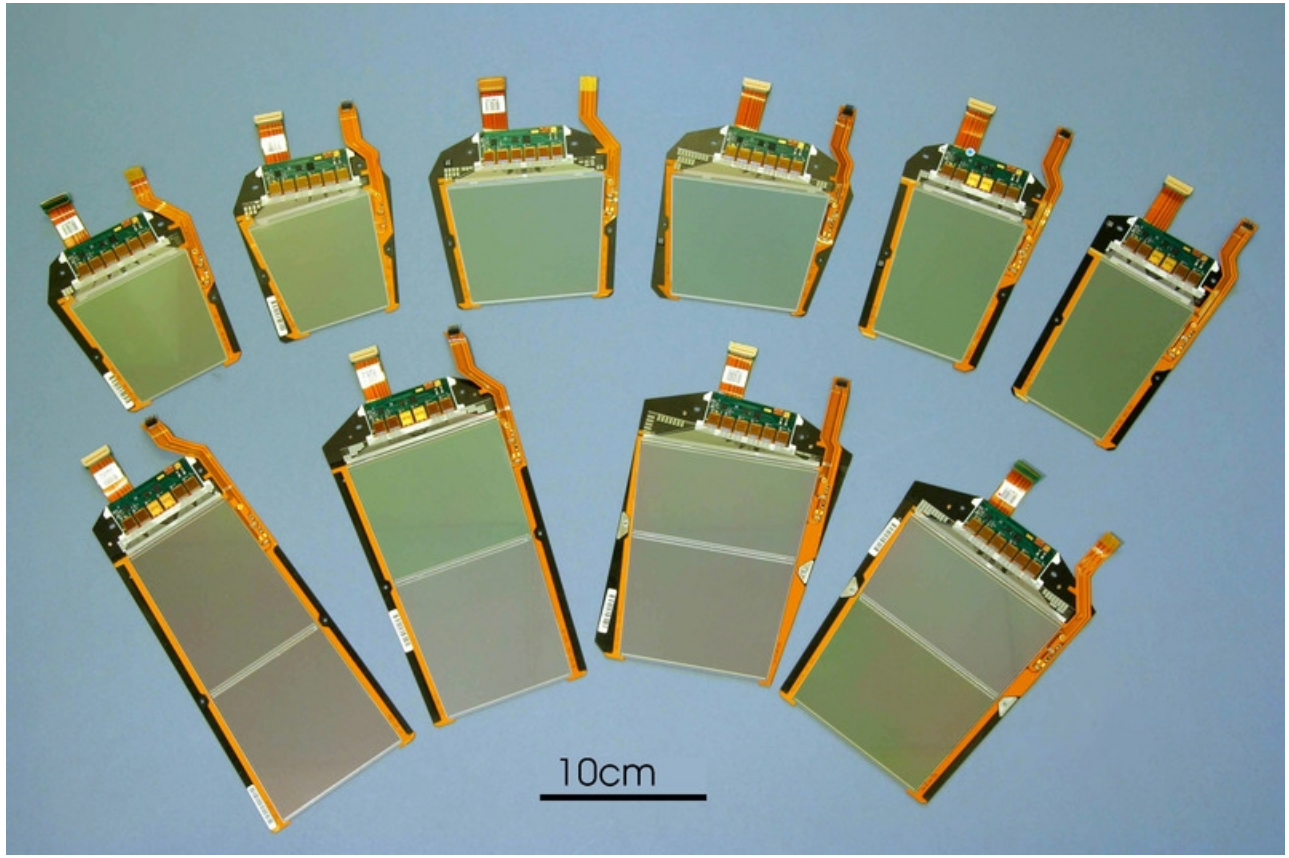


- Ten(!) different sensors for TEC
- (TIB: 2, TOB: 2,
  TID: 1 own + 2 shared w. TEC)
- Sensor layout in reality:
  - Outer shape
  - Active area
  - Strips
  - Bonding pads
  - Bias ring
  - Guard ring
  - Alignment markers
- Outer shape and active area are **trapezoids**
- Strips have **radial topology** (i.e. constant angle between strips)

TEC sensor manufacturers and implications

- Two sensor manufacturers: Hamamatsu (HPK) and ST Microelectronics (STM)
  - Ring 1-4: HPK only
  - Ring 5-7: HPK and ST
    - Most should be HPK, only few ST. Exact position and number of ST modules is available from TrackerDB, but not known to CMSSW.
- Differences between HPK and ST:
  - Sensors active area and total area are different.
  - The ST sensor active area width or length differs by -19...28 micron depending on the sensor type. Also strips have different length.
    - Only important for efficiency studies, not for alignment
  - The thickness of the active area also differs but is a manufacturers secret
    - Will have impact on w position of sensor → already studied (B. Hoob.)
- Equivalent angular width and strip positioning for ST and Hamamatsu
  - According to e-mail conversation with Pisa group
- → In CMSSW geometry, all sensors are assumed to be HPK sensors.

- Ring 1-4:
  single sensor
- Ring 5-7:
  two sensors
- Ring 1,2,5: Normal and stereo modules (sensors are the same, only different frame!)
- CMSSW description of two-sensor modules:
  One large sensor covering full area, no inactive zone between sensors
- Strip pitch in two-sensor modules matches only if sensors **exactly** placed!

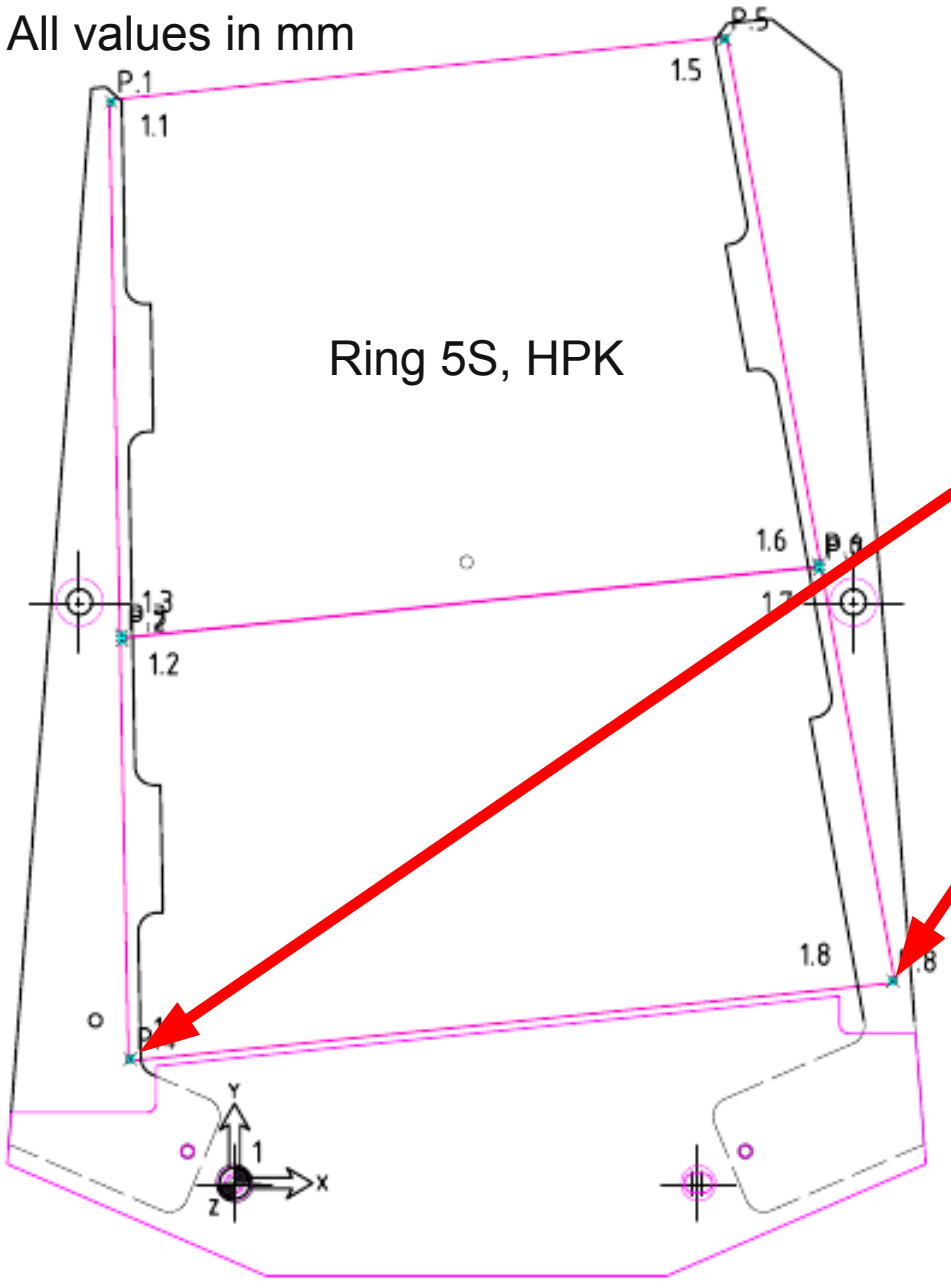


Are all two-sensors modules built in the same way?

- In principle, yes. There were exact specifications.
- Practically, no.

TEC module assembly

All values in mm



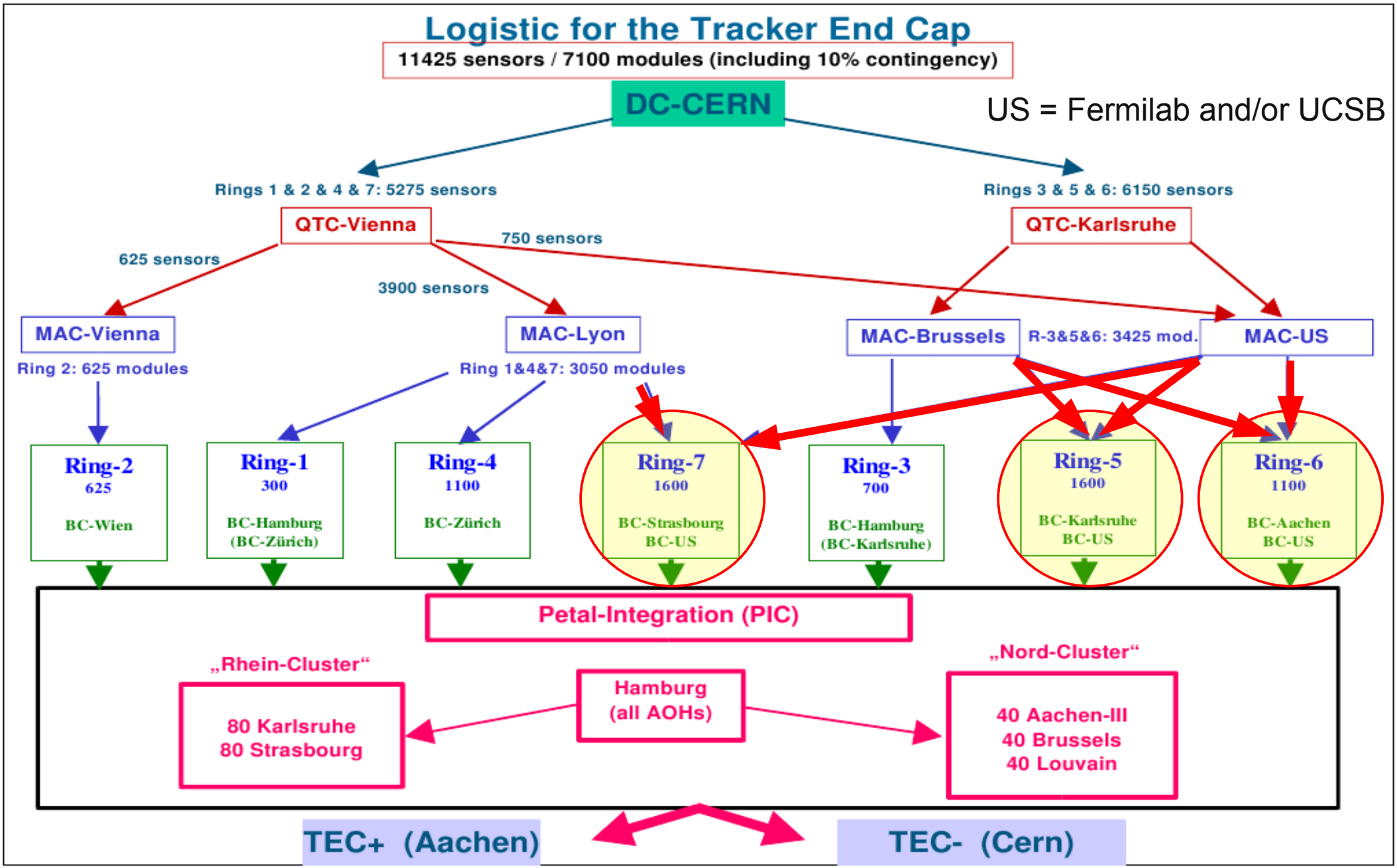
Nominal

Pos.	X	Y
1.1	-19.67	169.401
1.2	-17.969	85.056
1.3	-17.964	85.8
1.4	-16.615	19.479
1.5	78.215	179.222
1.6	93.151	96.949
1.7	93.304	96.221
1.8	105.005	31.682

Pisa Mask Data 03.06.

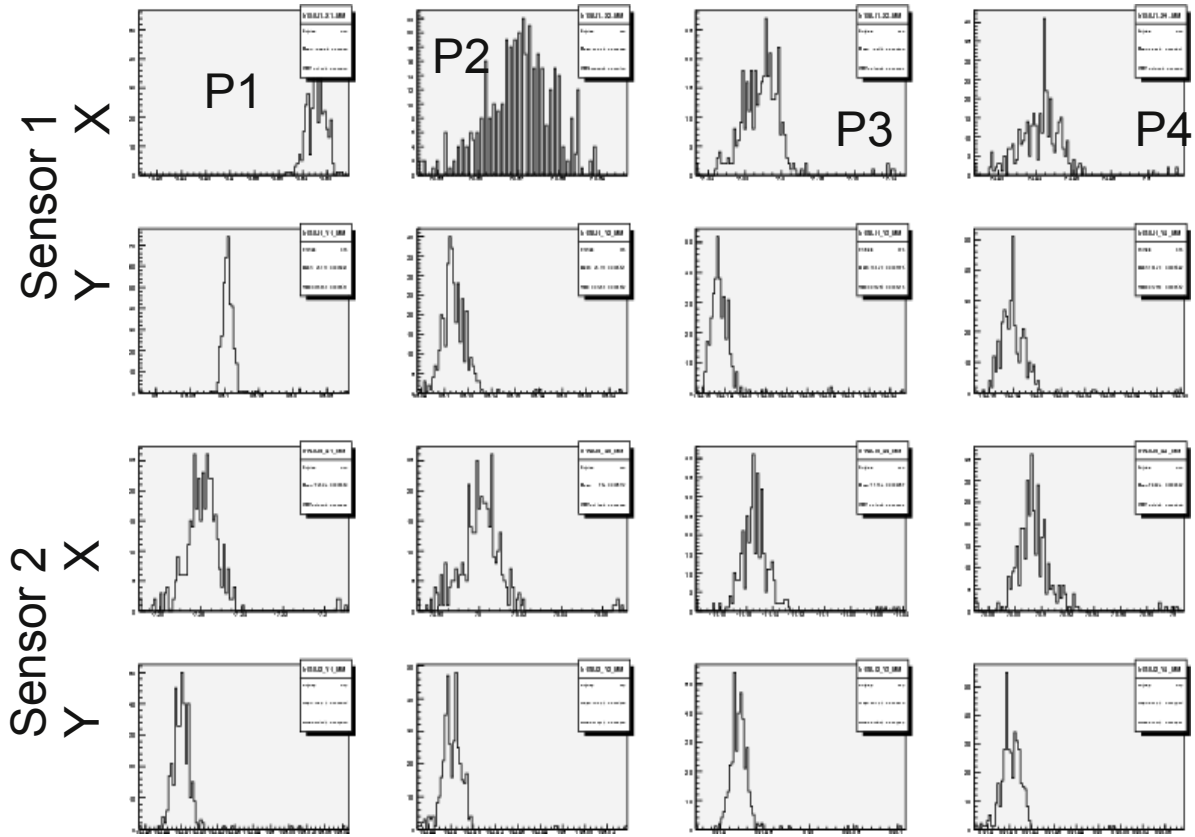
Pos.	X	Y
P.1	-19.67	169.401
P.2	-17.969	85.054
P.3	-17.964	85.801
P.4	-16.567	19.484
P.5	78.214	179.223
P.6	93.151	96.95
P.7	93.304	96.219
P.8	104.957	31.678

- First source of systematics: Difference between optimal placement ("pisa mask") and nominal assembly drawing
- Mostly identical values, some differences ~ few micron (i.e. below assembly precision)
- Largest Diff: Ring 5N, 5S
  Both HPK and ST versions ~50µm


Logistic for the Tracker End Cap
11425 sensors / 7100 modules (including 10% contingency)
DC-CERN
US = Fermilab and/or UCSB
Rings 1 & 2 & 4 & 7: 5275 sensors
Rings 3 & 5 & 6: 6150 sensors
QTC-Vienna
QTC-Karlsruhe
625 sensors
750 sensors
3900 sensors
MAC-Vienna
MAC-Lyon
MAC-Brussels
R-3&5&6: 3425 mod.
MAC-US
Ring 2: 625 modules
Ring 1&4&7: 3050 modules
Ring-2
625
BC-Wien
Ring-1
300
BC-Hamburg
(BC-Zürich)
Ring-4
1100
BC-Zürich
Ring-7
1600
BC-Strasbourg
BC-US
Ring-3
700
BC-Hamburg
(BC-Karlsruhe)
Ring-5
1600
BC-Karlsruhe
BC-US
Ring-6
1100
BC-Aachen
BC-US
Petal-Integration (PIC)
„Rhein-Cluster“
„Nord-Cluster“
80 Karlsruhe
80 Strasbourg
Hamburg
(all AOHs)
40 Aachen-III
40 Brussels
40 Louvain
TEC+ (Aachen)
TEC- (Cern)

Did gantry centers use nominal values?

- Gantry module assembly precision ~10µm
- After module assembly (and curing of glue) sensor positions are measured by gantry
  - Extract values from TrackerDB and see if they agree with the specs
  - 25 different datasets: 10 geometries x number of gantry centers, 16 histos each



R7N_Fermilab_HPK
Small game: Compare the numbers!
(Left: Measured mean; Right: Optimal)

Sensor 1 coordinates

	X	Y
P.1	70.5703	25.1085
P.2	74.9423	134.18
P.3	-7.2109	134.176
P.4	-2.82912	25.1054

Sensor 2 coordinates

	X	Y
P.1	75.0008	134.901
P.2	78.8947	231.921
P.3	-11.1528	231.922
P.4	-7.25882	134.901

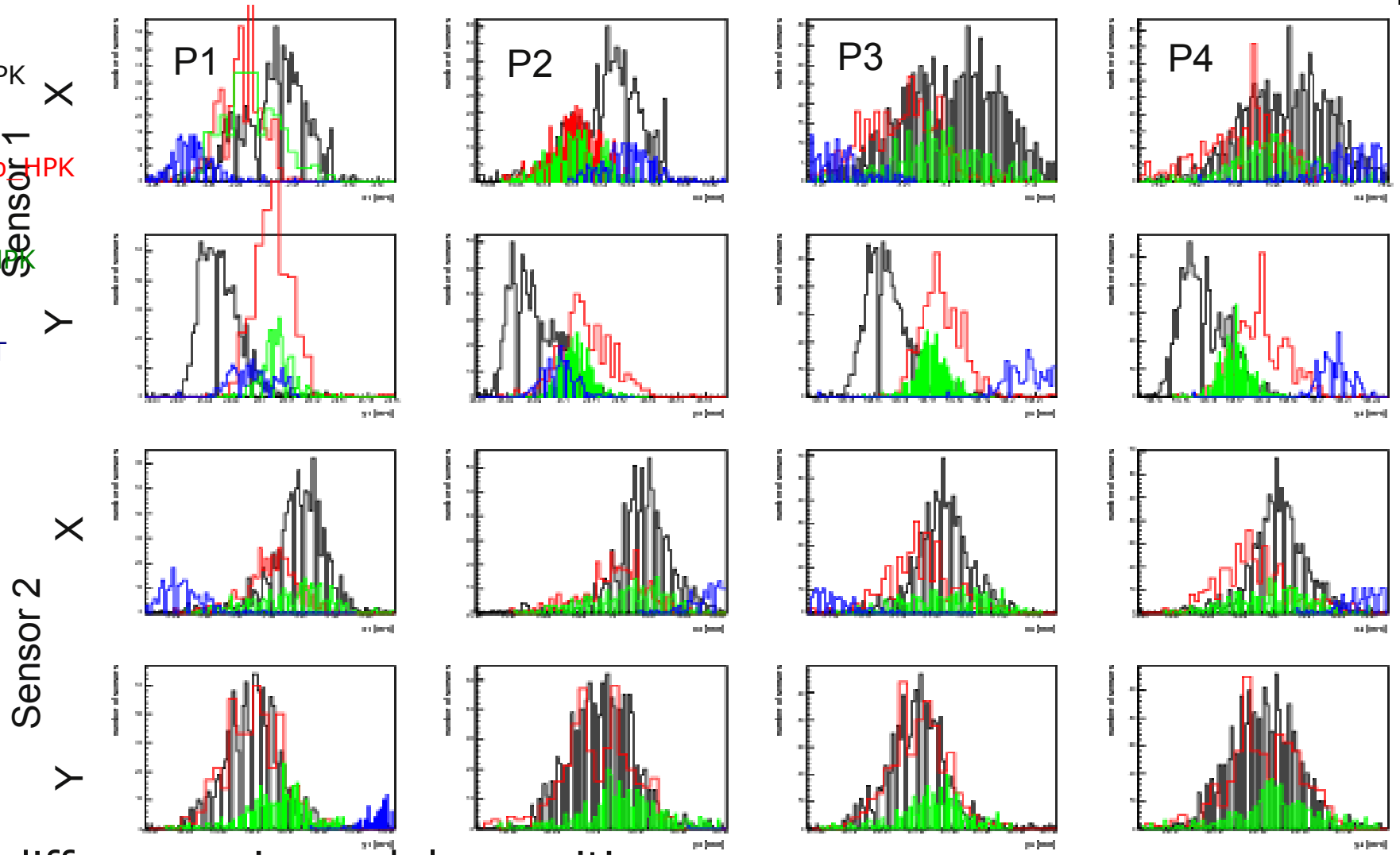
Pisa Mask Data 03.06.

Pos.	X	Y
P.1	-11.151	231.93
P.2	-7.257	134.908
P.3	-7.204	134.168
P.4	-2.827	25.098
P.5	70.573	25.098
P.6	74.95	134.168
P.7	75.002	134.908
P.8	78.896	231.93

Result: Good agreement within 10 µm

Differences between gantry centers

- Ring 7 comparison between gantry centers
  - Black: R7N_Lyon_HPK
  - Red: R7N_Fermilab_HPK
  - Green: R7N_UCSB_HPK
  - Blue: R7N_Lyon_ST



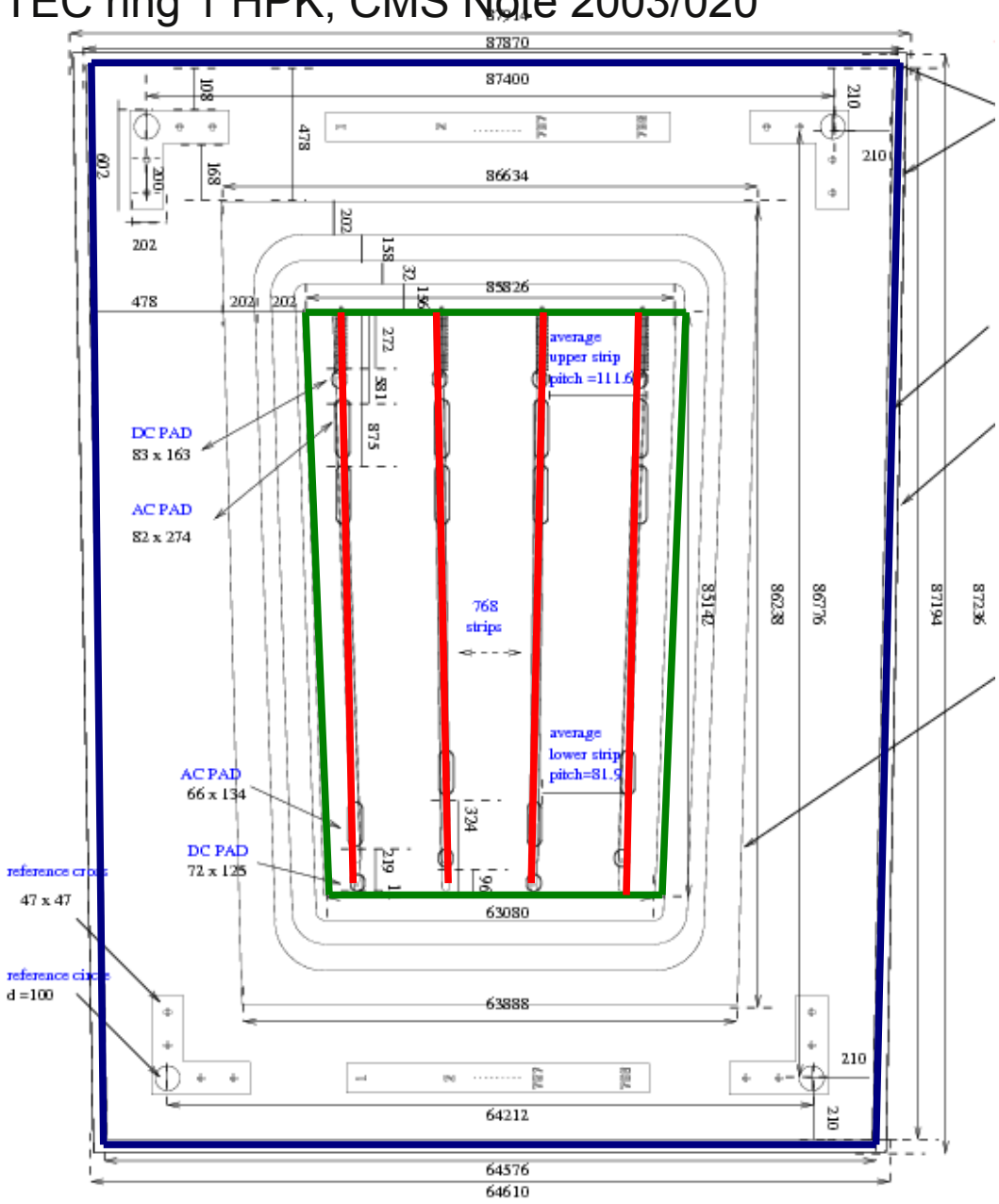
- Notable differences in modules positions.
  Different for sensor 1 and sensor 2, about 10–40 µm.

Part II

Module representation in CMSSW

TEC/TID sensor layout

TEC ring 1 HPK, CMS Note 2003/020



- Sensor layout in reality:
  - Outer shape
  - Active area
  - Strips
- Input to CMSSW geometry:
  - Outer shape
  - Active area
  - Number of strips
- In CMSSW, strip positions are calculated from number of strips and active area
- → Active area is different in reality and CMSSW simulation
  - Size is adjusted in CMSSW to reproduce correct angular pitch
  - In reality, more space next to first and last strip

1. Extract sensor values from CMS Note, put in C++ class

```
const int nRings = 16;
/** These are values from the drawings / CMS note 2003/020 */
AngularModule pisa_module[nRings] = {
  AngularModule("TEC Ring 1 HPK",  768, 0.019852, 235100,  85160,  87236,  64610,  87914),
  AngularModule("TEC Ring 2 HPK",  768, 0.01985,  323000,  88160,  90236,  88096, 112202),
  AngularModule("TEC Ring 3 HPK",  512, 0.01799,  392100, 110660, 112736,  64904,  83012),
  AngularModule("TEC Ring 4 HPK",  512, 0.012856, 504100, 115160, 117236,  59730,  73179),
  AngularModule("TEC Ring 5A ST",  768, 0.011909, 603200,  81169,  83994,  98976, 112355),
  AngularModule("TEC Ring 5B ST",  768, 0.011909, 687293,  63198,  66023, 112432, 122918),
  AngularModule("TEC Ring 6A ST",  512, 0.012847, 727000,  96136,  98961,  86100,  97385),
  AngularModule("TEC Ring 6B ST",  512, 0.012847, 826060,  84936,  87761,  97470, 107465),
  AngularModule("TEC Ring 7A ST",  512, 0.009,    888400, 106926, 109751,  74047,  82874),
  AngularModule("TEC Ring 7B ST",  512, 0.009,    998252,  94876,  97701,  82933,  90786),
  AngularModule("TEC Ring 5A HPK", 768, 0.011909, 603200,  81171,  83946,  98952, 112354),
  AngularModule("TEC Ring 5B HPK", 768, 0.011909, 687293,  63225,  65983, 112382, 122914),
  AngularModule("TEC Ring 6A HPK", 512, 0.012847, 727000,  96148,  99040,  86184,  97207),
  AngularModule("TEC Ring 6B HPK", 512, 0.012847, 826060,  84948,  87840,  97547, 107285),
  AngularModule("TEC Ring 7A HPK", 512, 0.009,    888400, 106953, 109712,  74012,  82818),
  AngularModule("TEC Ring 7B HPK", 512, 0.009,    998252,  94904,  97662,  82872,  90713)
};
```

2. Extract sensor positioning values from module assembly drawings (gap between sensors in two-sensor modules)

3. Consistency check for two-sensor modules: Compare expected strip position with actual strip position
(continuing strips from first module to second module → 10 µm syst!)

3. Create .xml files for CMSSW geometry description

```
<Constant name="FullHeight"        value="20.7474000*cm"/>
<Constant name="ActiveHeight"      value="20.4715500*cm"/>
<Constant name="DlTop"             value="9.0713000*cm"/>
<Constant name="DlBottom"          value="7.4012000*cm"/>
<Constant name="SideWidthTop"      value="0.1376009*cm"/>
<Constant name="SideWidthBottom"   value="0.1262048*cm"/>
```

4. Validate: Run CMSSW and watch creation of RadialStripTopology

RadialStripTopology: constructed with strips = 768 width = 3.464828e-04 rad det_height = 1.108580e+01 ctoi = 2.867290e+01 phi_edge = 1.330494e-01 rad y_ax_ori = -1 y_det_centre = 0.000000e+00
RadialStripTopology: constructed with strips = 768 width = 3.464828e-04 rad det_height = 1.108580e+01 ctoi = 2.867290e+01 phi_edge = 1.330494e-01 rad y_ax_ori = -1 y_det_centre = 0.000000e+00
RadialStripTopology: constructed with strips = 768 width = 3.464477e-04 rad det_height = 8.816000e+00 ctoi = 3.670801e+01 phi_edge = 1.330359e-01 rad y_ax_ori = -1 y_det_centre = 0.000000e+00
RadialStripTopology: constructed with strips = 768 width = 3.464477e-04 rad det_height = 8.816000e+00 ctoi = 3.670801e+01 phi_edge = 1.330359e-01 rad y_ax_ori = -1 y_det_centre = 0.000000e+00

- Validation: Convert values back to input values (i.e. those from sensor drawing)

```
AngularModule "TEC Ring 1", 768, 0.019852, 235100,  85160
AngularModule "TEC Ring 1", 768, 0.019852, 235100,  85160
AngularModule "TEC Ring 2", 768, 0.019850, 323000,  88160
AngularModule,"TEC Ring 2", 768, 0.019850, 323000,  88160
AngularModule "TEC Ring 3", 512, 0.017990, 392100, 110660
AngularModule,"TEC Ring 4", 512, 0.012856, 504100, 115160
AngularModule,"TEC Ring 5", 768, 0.011909, 603200, 147262
AngularModule,"TEC Ring 5", 768, 0.011909, 603200, 147262
AngularModule,"TEC Ring 6", 512, 0.012847, 727000, 184088
AngularModule,"TEC Ring 7", 512, 0.009000, 888400, 204715
# For modulesin in rings 5,6,7 , need to compute the active length of
# two-sensor modules from pisa module table. This is the computation:
# root [1]  81171+(83946-81171)/2.+100+(65983-63225)/2.+63225
#  81171+(83946-81171)/2.+100+(65983-63225)/2.+63225
# (const double)1.47262500000000000e+05
# root [2] 96148+(99040-96148)/2.+100+(87840+84948)/2.
# 96148+(99040-96148)/2.+100+(87840+84948)/2.
# (const double)1.84088000000000000e+05
# root [3] (109712+106953)/2.+100+(97662+94904)/2.
# (109712+106953)/2.+100+(97662+94904)/2.
# (const double)2.04715500000000000e+05
```

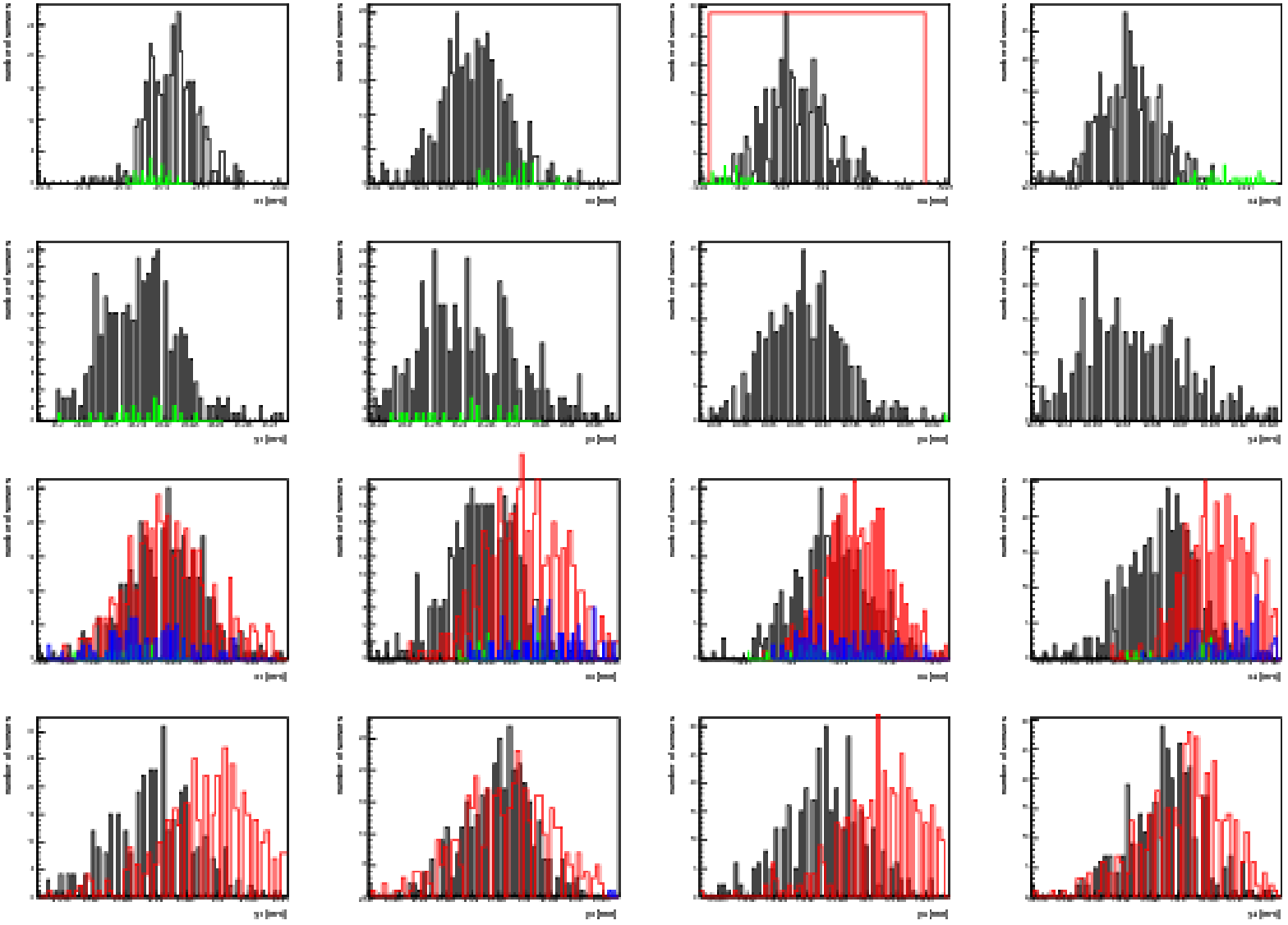
- Validation: Compare to values from sensor drawings (page 14)
- Result: Excellent agreement within < 1 µm!

Summary and conclusion

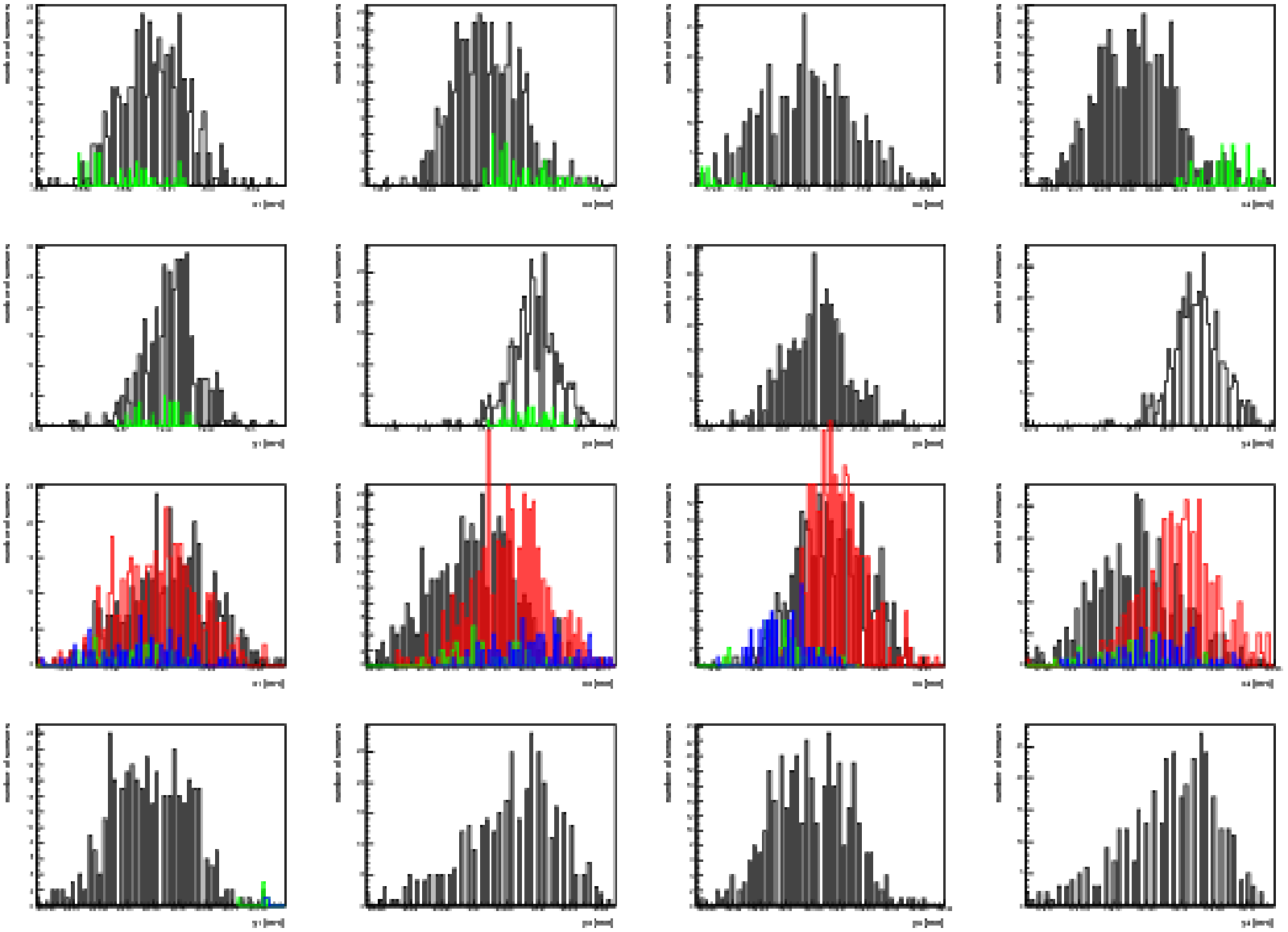
- Sensor description in CMSSW has been validated
  - Optimal description, i.e. equivalent to sensor drawings!
- Precision of module assembly has been assessed from measurements
  - Effect 1: Module drawings
    Some module drawings were slightly wrong, 2nd sensor ~ 50 µm in x!
  - Effect 2: Gantry implementation of module drawings
    Sometimes, wrong input values used on gantry: ~ 10 – 40 µm in x!
  - Effect 3: Differences between STM and HPK sensors
    Not assessed, assume everything to be HPK sensors, ~ ?? µm
  - Effect 4: Gantry precision
    Statistical scatter of module x with RMS ~ 10 µm
- Conclusion:
  - In principal, a complicated SQL query + math gymnastics can give precise module position of 2nd sensor
  - Experience: Better measure position with real data! (á la Claus...)
  - Also verify the strip pitch from data!

BACKUP

- Ring 5N (Brussels confused P1,P2,P3,P4 for sensor 1during DB upload)
- Black:
  UCSB HPK
- Red:
  Brussels HPK
- Green:
  UCSB ST
- Blue:
  Brussels ST



- Ring 5S (Brussels confused P1,P2,P3,P4 for sensor 1during DB upload)
- Black:
  UCSB HPK
- Red:
  Brussels HPk
- Green:
  UCSB ST
- Blue:
  Brussels ST



- Ring 6 (Brussels confused P1,P2,P3,P4 for sensor 1 during DB upload)
- Black:
  UCSB HPK
- Red:
  Brussels HPK
- Green:
  Brussels LAS