MaPSA ASSEMBLY Testing Specification

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General Information

1) Overall Description:

In view of the High Luminosity LHC upgrade, the CMS tracker needs to be upgraded to match the new physics requirements. The detector modules for the new tracker will feature higher granularity, lower mass, as well as the ability to correlate locally the signals from two silicon sensors.

A module consists of silicon sensors (segmented in pixels or strips), front-end hybrid circuits carrying the readout ASICs, service hybrids carrying the auxiliary electronics, and a lightweight mechanical assembly providing structural support and efficient thermal contacts to remove the heat produced by the electronics and the silicon sensors.

The assembled modules must work reliably in a harsh environment featuring high radiation levels (up to 2×10^{15} n_{eq}/cm^2 integrated particle fluence), strong magnetic field (4T) and large temperature variations (from 25°C to −35°C), with no possibility of maintenance and repairs over an expected time frame of more than a decade.

Different module types are under development, matching the requirements of different regions of the tracker, and resulting in different degrees of complexity and specific technological solutions. For each module type, different options are considered and developed to make best use of the available commercial technologies, and to fulfil the requirements. This document deals with the development of module subassemblies for the inner tracker area of the CMS experiment. The PS modules contain a strip sensor on the top layer and a pixelated strip sensor on the bottom layer. This topology requires the Macro Pixel ASIC chip (MPA) to be directly bumped to the pixelated strip sensor. The PS

module will ultimately require sixteen MPA chips (each with a size of 12 mm x 26 mm and containing 1918 bumps) to be connected to a single large area sensor piece (Figure 1).

The MaPSA subassembly (Figure 2) contains sixteen MPA chips bumped to the pixelated sensor. It is connected through a wirebond-array to the front-end hybrid and to the service hybrids. The sensors are 320 microns thick. The MPA chips are 250 microns thick.

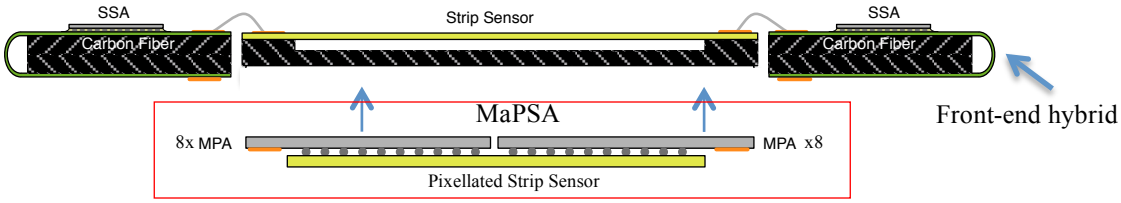

Figure 1. MaPSA assembly in RED box

2) Quantities

For reference, we also include a description of the production phase of the project with an estimate of quantities:

a) 20 Dummy assemblies are complete
b) 25 round 1 prototype assemblies – in process
    a. 10 active MaPSA assemblies
    b. 15 setup-dummy assemblies using top metal only setup parts.
c) ~80 (40+40 round 2) MaPSA prototypes, depending on parts availability for pilot testing
d) 6456 MaPSAs are to be built and tested:
    a. 5616 production
    b. 840 spares

The vendor will test ~40 of the MaPSA prototype modules from c).

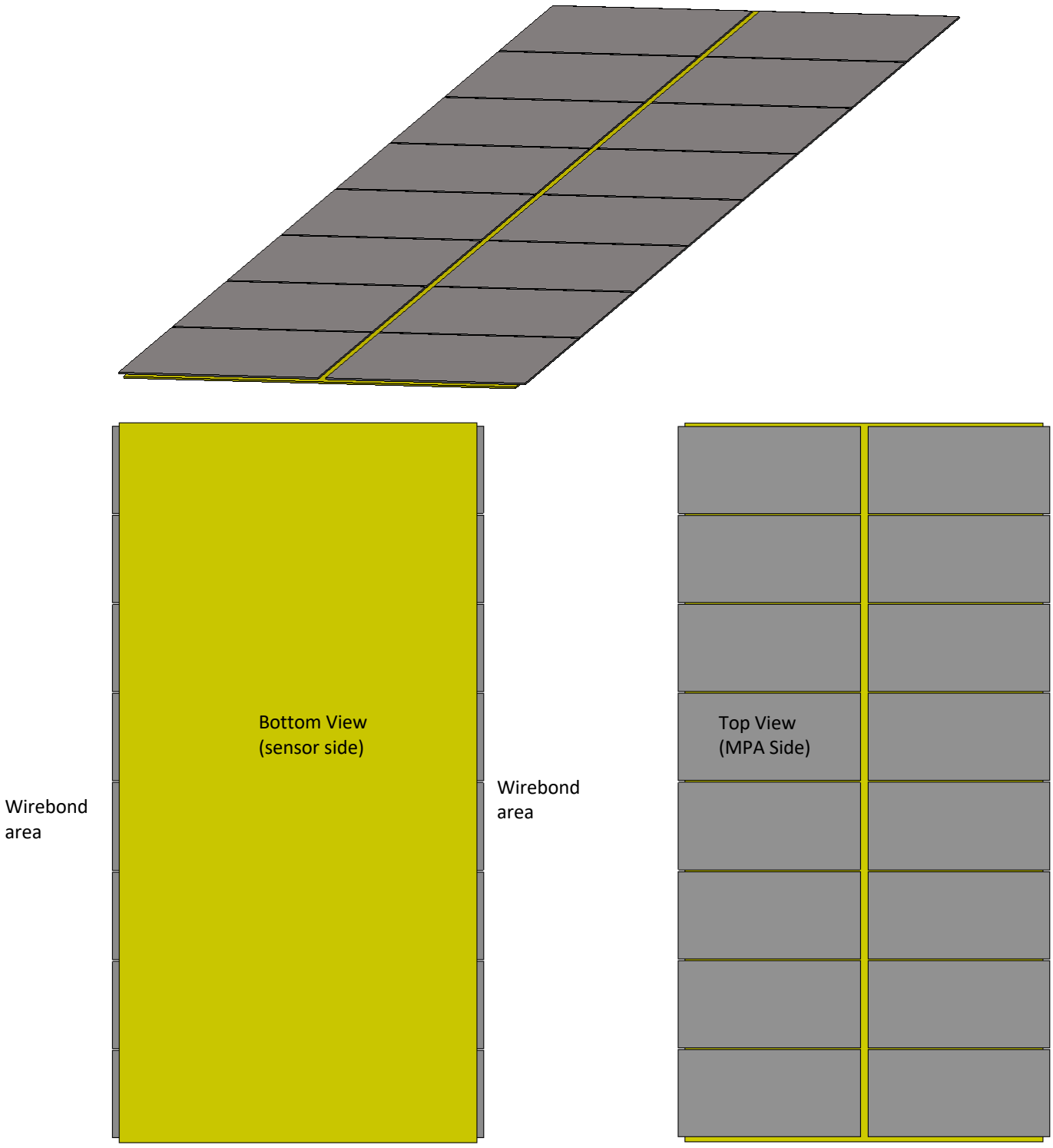

Figure 2. Drawings of MaPSA assembly layout of 2 x 8 columns of 8 MPA chips on an approximately 5 x 10 cm 1 PS-p Sensor with 100 micron chip spacing.

3) **Handling**
   a) The MaPSAs are static sensitive. The tester must conform to the ANSI/ESD 20.20 static protection program.
   b) Conditions:
      i) Cleanroom equivalent to class 10,000 or better
      ii) Temperature: 17°C to 28°C
      iii) Humidity: Handling room humidity must be maintained between 45 and 55%
   c) The MaPSA sensors are susceptible to damage due to scratches or mishandling on both top and bottom surfaces. MaPSAs must be handled with appropriate vacuum tweezers. The assemblies should never be slid across hard surfaces that might cause scratch damage. Mouth protection should be worn when handling parts. Direct contact with skin must be avoided.
   d) MaPSAs should be stored in a dry box before testing.

4) Inspection

Before and after testing each MaPSA should be inspected for damage. Any issues must be documented.

5) Additional requirements

Parts are to be delivered from the assembler in static-dissipative packaging agreed with Fermilab. All parts handling will include documented ESD protection. After testing, parts should be stored and shipped using this original packaging.

6) Electrical Testing

1. Description

   The MaPSA module consists of a sensor bump-bonded to 16 Macro Pixel Assembly (MPA) readout integrated circuits. The chips are assembled in two columns of 8 chips with wirebond pads and associated test pads at the outer long edges. MPA chips have 118 wirebond pads on 100 micron pitch. Each pad has a 100x70 micron region for probe testing and a 200x70 micron area for final wirebonding (Figure 3).

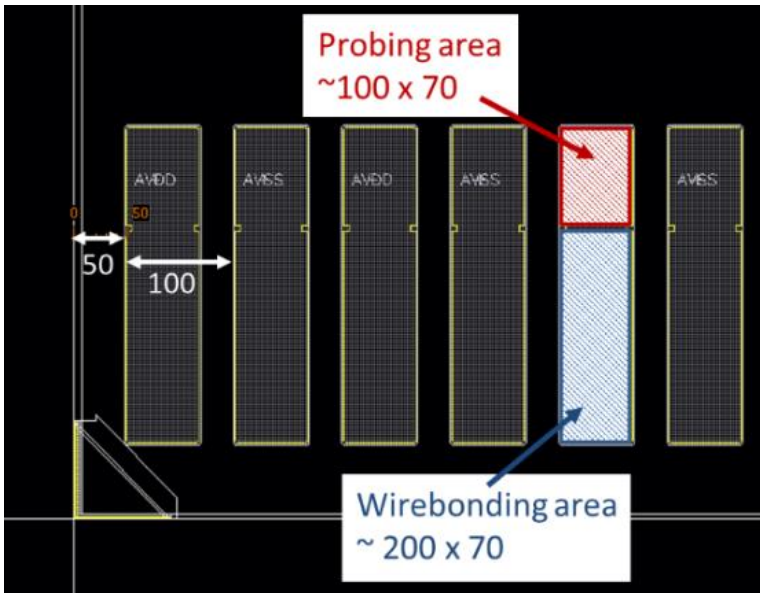

Figure 3. Bond pad geometry.

2. Parts
   The MaPSA should be tested on a 6" or larger semi-automatic probe station or other equipment capable of contacting pads on 100 micron pitch. CMS/Fermilab can provide:
   a. Probe card(s) (117 needles)
   b. Test system including:
      i. associated readout system (FC7 FPGA card, Interface card)
      ii. power supplies (LV), HV Bias supply with picoammeter
      iii. Test software for Linux computer
      iv. Linux host computer
      v. Connecting cables

   The sensor backside is contacted with a separate stand-alone probe.

3. MaPSA Electrical Tests
   Prior to electrical testing the MaPSA should be visually inspected to verify soundness for testing.

   The vendor can choose a full testing system (software and hardware provided by CERN/FNAL) and/or standardized test code (e.g. STIL or equivalent) compatible with the vendor's ATE can be provided.

   For each MPA on the MaPSA the test sequence includes:
   a. Power on sequence/current measurement

b. Write/Read tests for individual chips, rows, and pixels
c. Verify lock with 320 MHz clock
d. Individual pixel test
    i. Pixel alive
    ii. Noise Measurement
    iii. Trim Test

Tests for each MPA should take >5 minutes, depending on test system speed. After a column of 8 chips is tested, the MaPSA must be rotated to access the second column. Pass/fail results of the testing will be reported by the testing software. Output files will be stored and delivered in electronic form to CMS

A high voltage test will be performed with a single MPA connected to the readout system. The system will record sensor currents up to a bias value of 600 Volts.

4. Documentation to be provided by Fermilab/CMS:
    a. Validation Test description
        i. Standard test code or vectors
    b. Assembly of test system and system schematics
    c. Operation of test system software

5. Acceptance
    a. Assembled MaPSA devices will be tested by the vendor to verify operation of the 16 chips and connectivity of the bumps. The test will also include verification of sensor functionality and leakage current after assembly.
    b. Bump yield must be >99% as determined by probe testing after assembly for any accepted assembly. Bump connectivity is determined by the noise in the associated MPA amplifier channel.
    c. The maximum sensor current cannot exceed 10 uA.

7) Documentation

Overall documentation will be provided in a format agreed between CMS/Fermilab and the testing vendor. This may be in the form of a database or electronic travelers.

a) All recordkeeping should refer to the sensor serial number. The production serial number of the sensor is provided as part of the sensor packaging and encoded in scratch pads on the sensor surface.
b) The testing vendor will note any anomalies that occurred due to mishandling.

c) Files written by the test program (described in “MaPSA Test Description”) will be provided by the testing vendor.

8) Location

Some parts may be subject to export control. Facilities should preferably be located within the United States, Canada, Japan, or Europe.

9) Drawings

Fermilab will provide GDS files of the sensor and readout chips as well as drawings of the full assemblies. The included drawings are for reference and context only.

10) Delivery

Assembled MaPSA modules will be packaged in static dissipative packaging using a design agreed with Fermilab.

11) Project Schedule

Prototypes 2018-2020

Production 2020-2022

12) Fabrication Documentation

Final documentation will be provided at the award of the contract.

13) Technical Contacts

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Figure 3. Setup MaPSA Assembly with the sensor side up.

Edge detail – wirebond pads exposed.

Figure 4. Setup MaPSA assembly with the MPA chips face up.

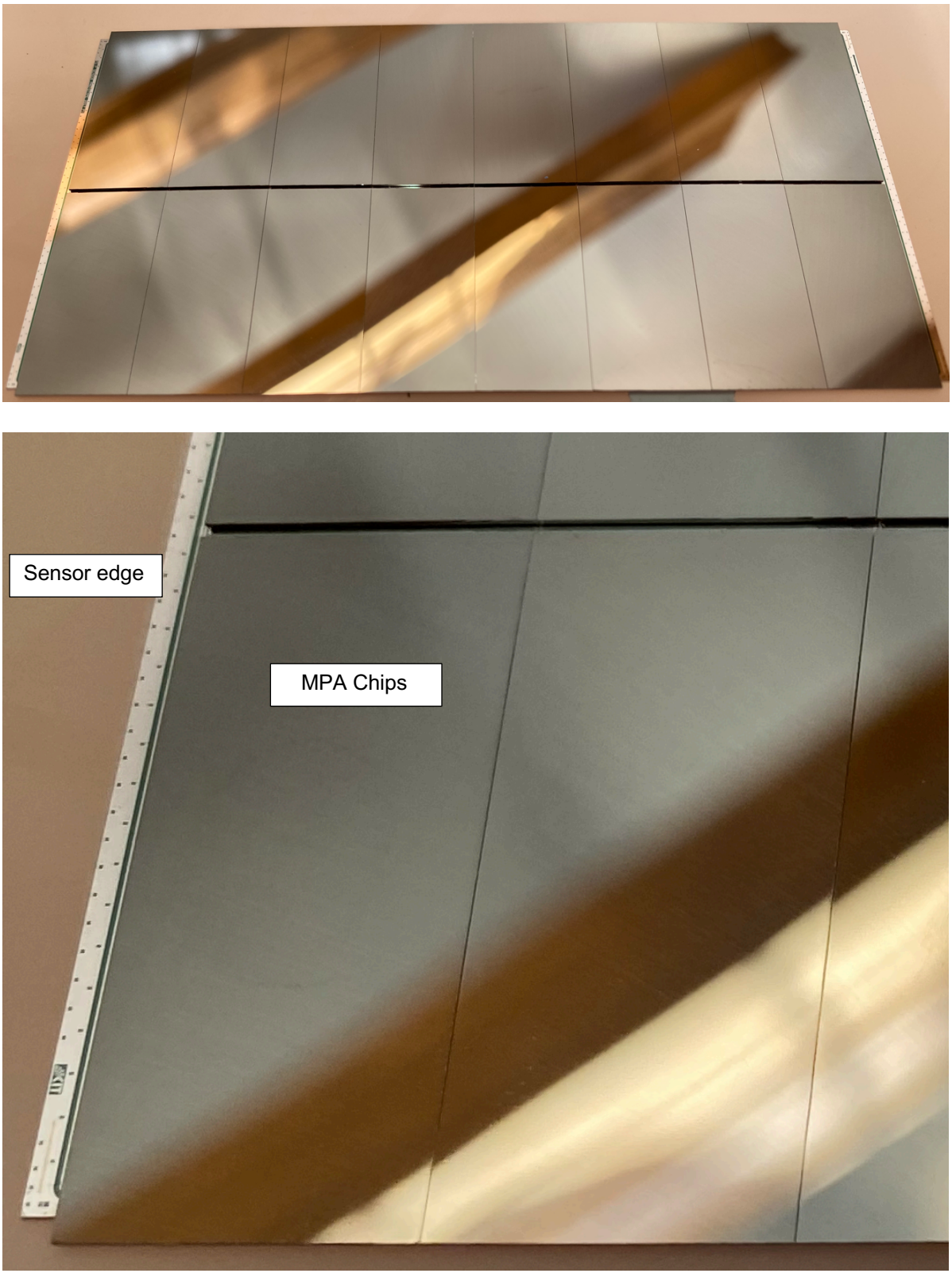

Figure 5. MaPSA Assembly edge region.

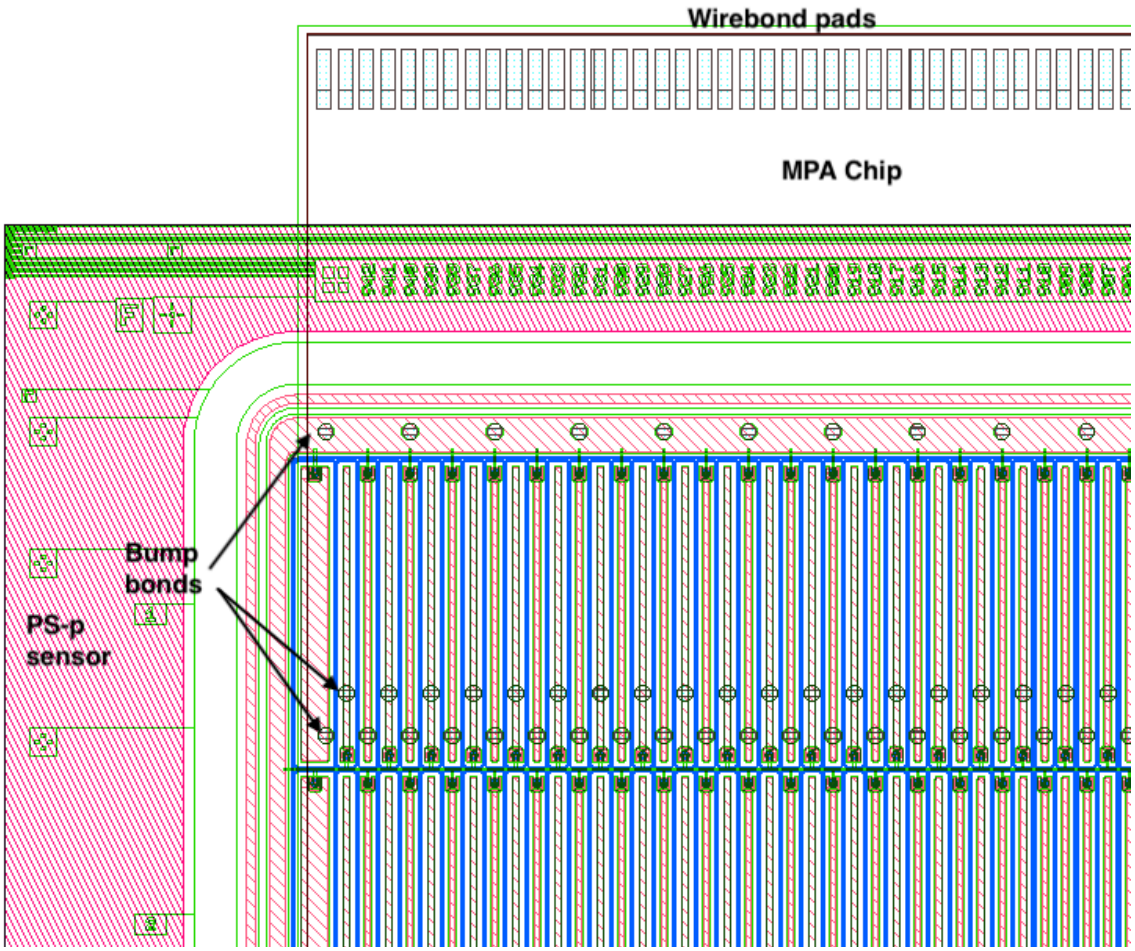

Figure 6. Diagram of the probe pads on MPA chip.

I/O conn. Wire bonding pads:

- Pad Pitch: 100 um
- Pad height: 250 um
- Pad width: 70 um
- Probing area: 100 x 70 um^2
- Wire-bonding area 150 x 70 um^2
- Full functionalities accessible with probing

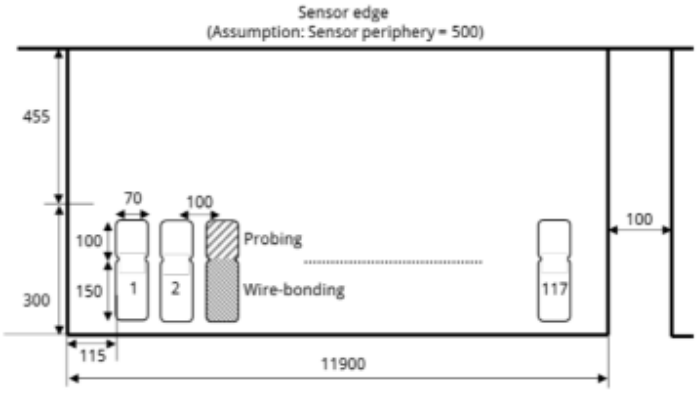

Figure 7. The Fermilab probe test setup.

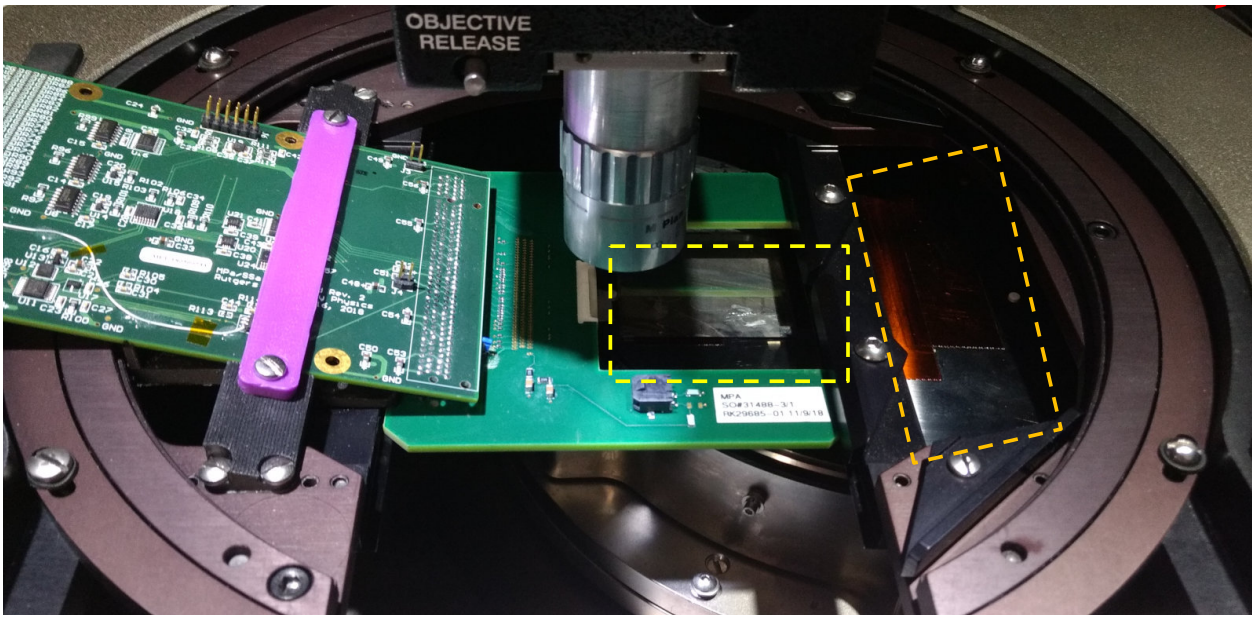

Figure 8. MPA Read Out Integrated Circuit dimensions: 16 rows of bumps separated by 1446 microns

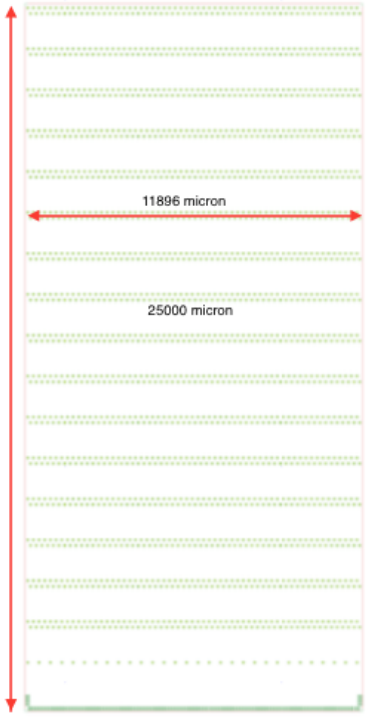

Figure 10. Sensor dimensions.

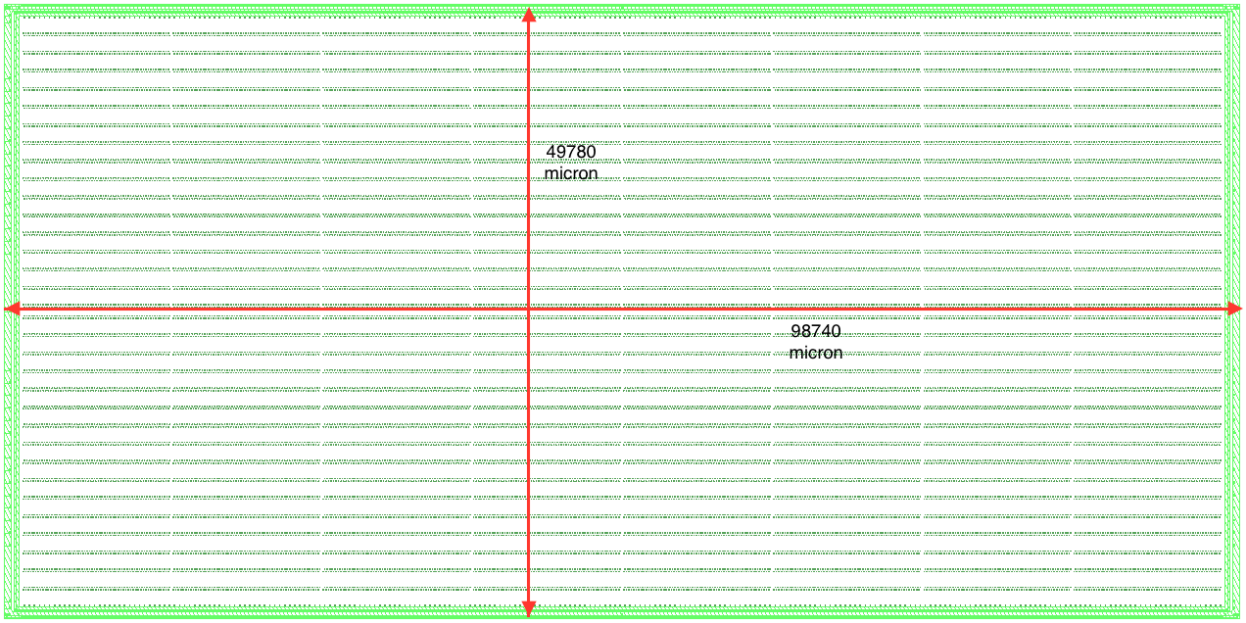

Figure 11. Top view of MaPSA with thermal bridges in position. Underfill must not wick up into the areas where the thermal bridges rest on the backs of the MPA chips

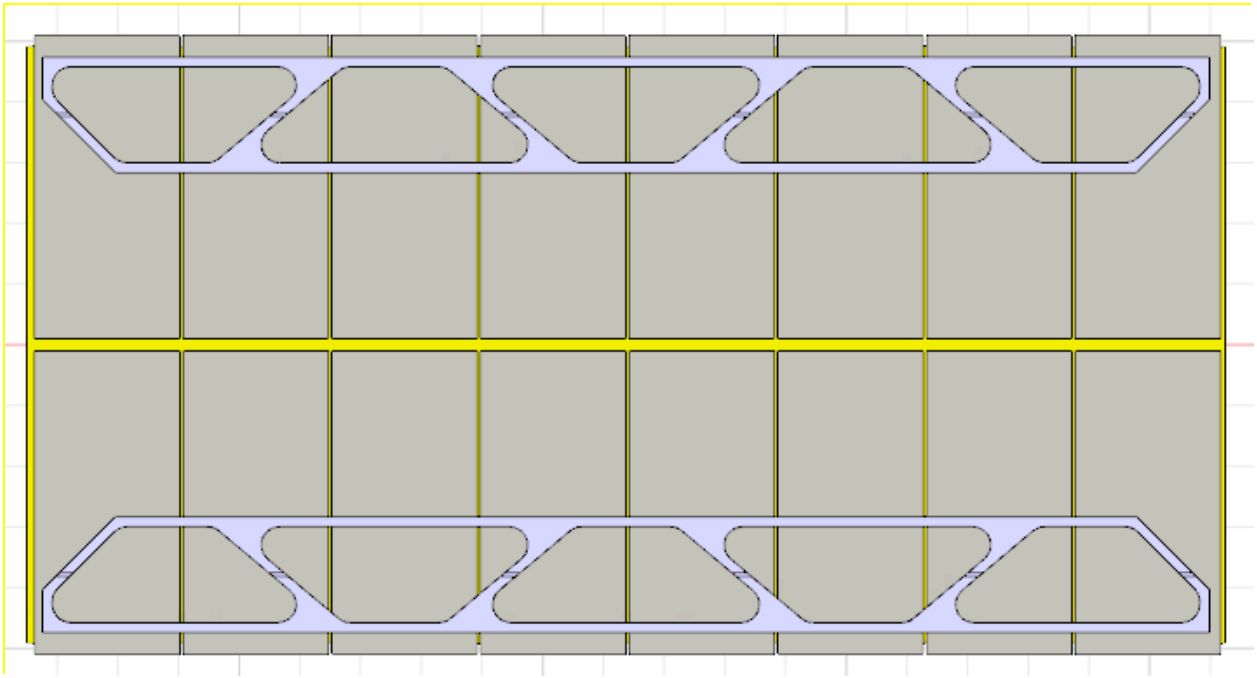

Figure 12. Full PS Module assembly

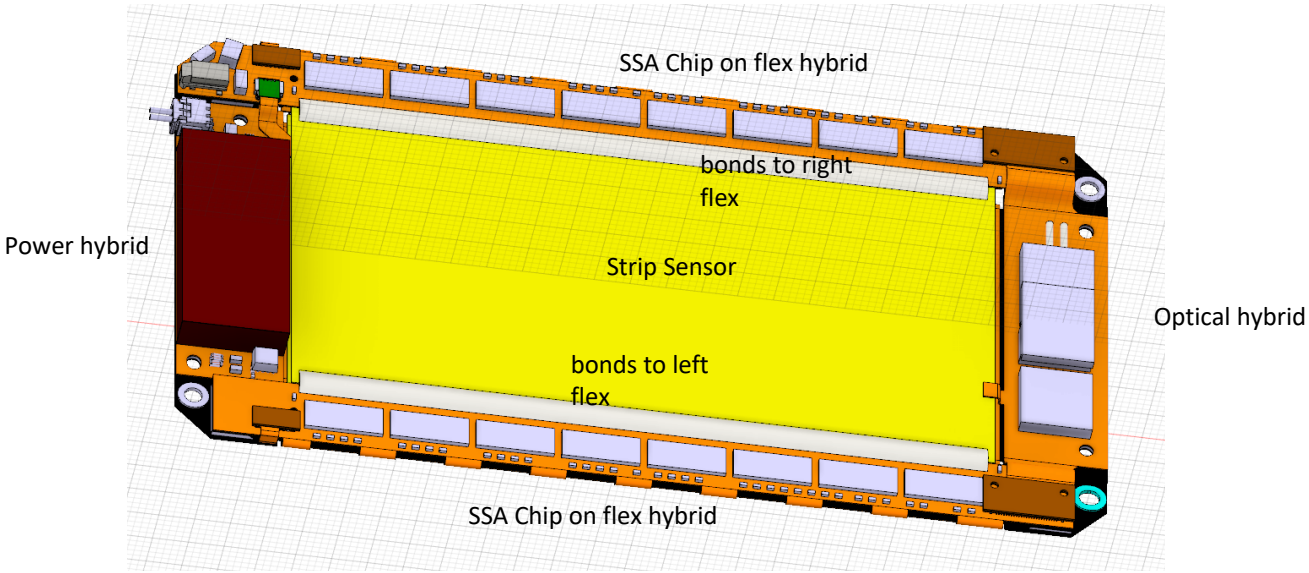

Figure 13. PS Module – Strip sensor removed showing the top of the MaPSA and Aluminum – Carbon (ALCF) fiber spacers