ePIC-BTOF用FPCの開発

ラダー用FPC
放熱テスト用試作のためのFPC

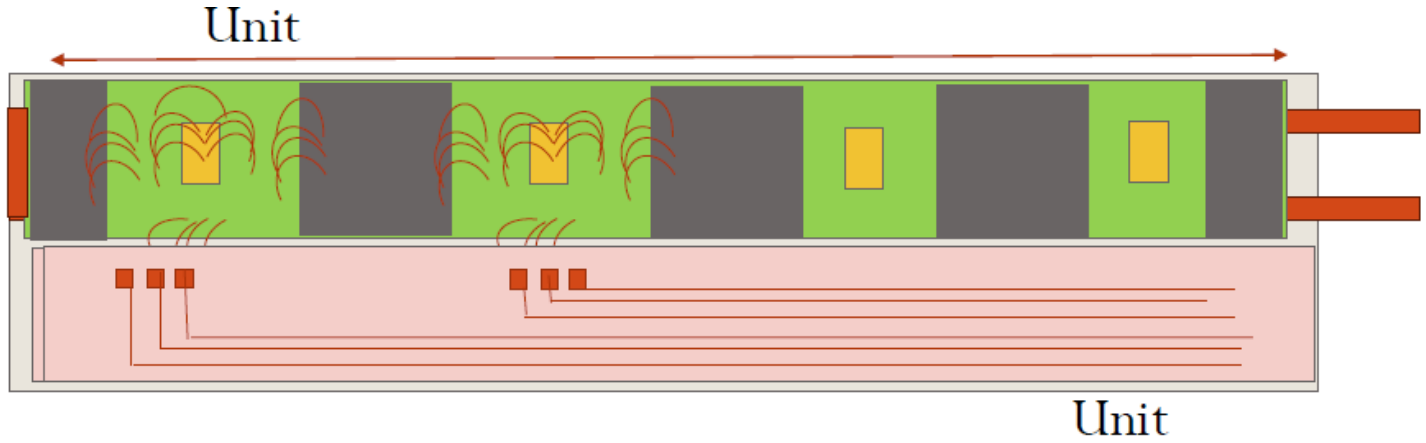
奈良女子大
蜂谷　崇

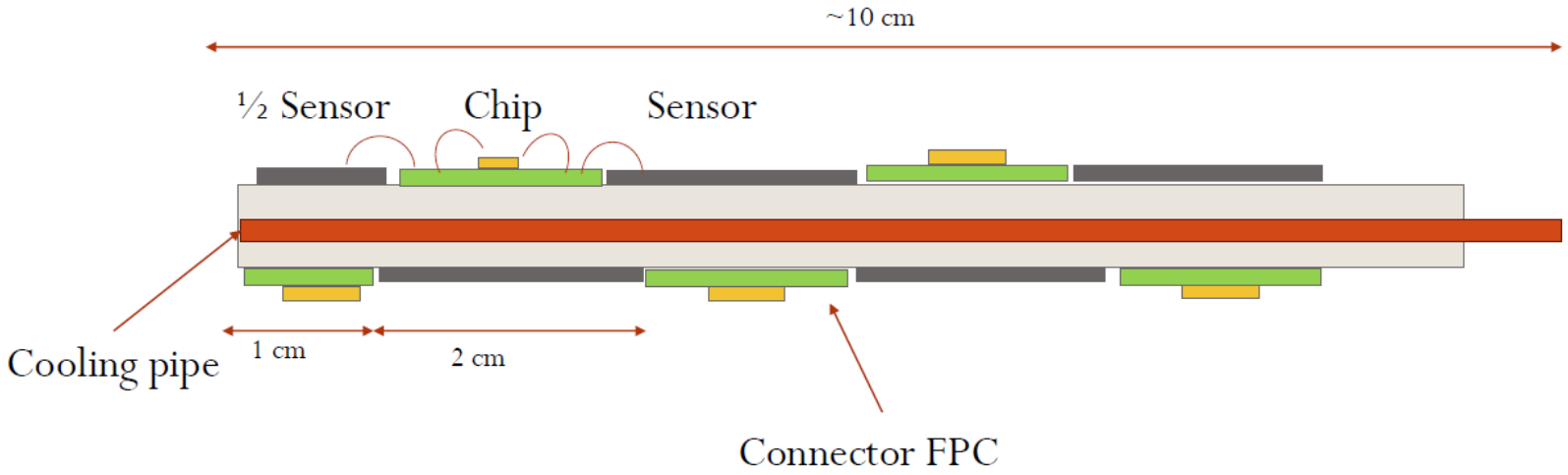
概要

- 2025/4/14 13:00~ ハヤシレピック社とFPC開発についての打ち合わせを行った。
  - レピック社：　曽我さん、星谷さん、柳川さん、
  - 中川さん、蜂谷、
- 検討項目
  1. 135㎝の長尺FPCは作れるか？　作れるとしたらどうやって。
  2. ThermometerProject用FPCを短期間でつくれるか。

これまで考えられていたデザイン

- 上半分がセンサー＋ASIC
- 下半分がFPC
  - FPC用のスペースとして、　下半分（2.5 cm）しかない。





～30cm程度のFPCをつなぐことは可能か？

- Ladder : 135cm long with 34 sensors and 34 ASICs

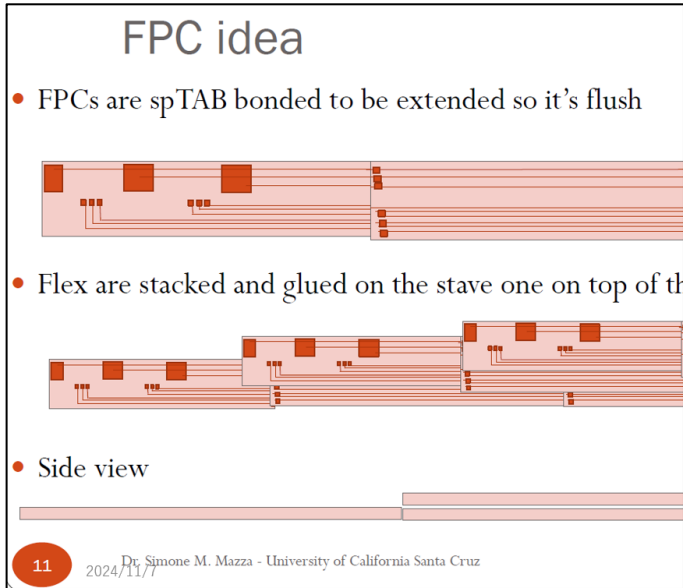
  - Minimize the additional connection
  - Assembling this very long module is difficult
    - Yield rate will be issue during the production

- If split by 3 pieces, each FPC is 50cm long

  - 50cm FPC can be made with minimum risk in production
    - Finer line & space available (60um x 60um)
  - Multiple connection needed
    - Reduce active area by connecting these FPCs

- How connect each other ~ 200 lines + power + GND
  - spTAB bonding
  - Connector (micro pitch)
    - Fragile, (not so reliable?)

Simone's slide in Nov. 2024



FPCを実現するために考えないといけないこと

- 135cmの長さ
  - どうやってつくるか？　実現可能か？
  - 形状はINTTのバスエクステンダ（最大130cm）に似ている
  - 全長を1枚？　複数をつなぐ？
  - つなぐ場合の方法？　TABボンディングは？
- FPC内の配線
  - 何層？
  - バスエクステンダの経験から1枚だと信号層は1層がよい　歩留まり
- ASICとFPCの接続
  - ワイヤーボンディングを想定
  - TABボンディング可能か？

- レピック社にTABボンディングの経験はない。　試作・テストが必要
- TABボンディングについて調べてくれる：　レピック社柳川さん
- 1枚

つなぐ方法

TABボンディング

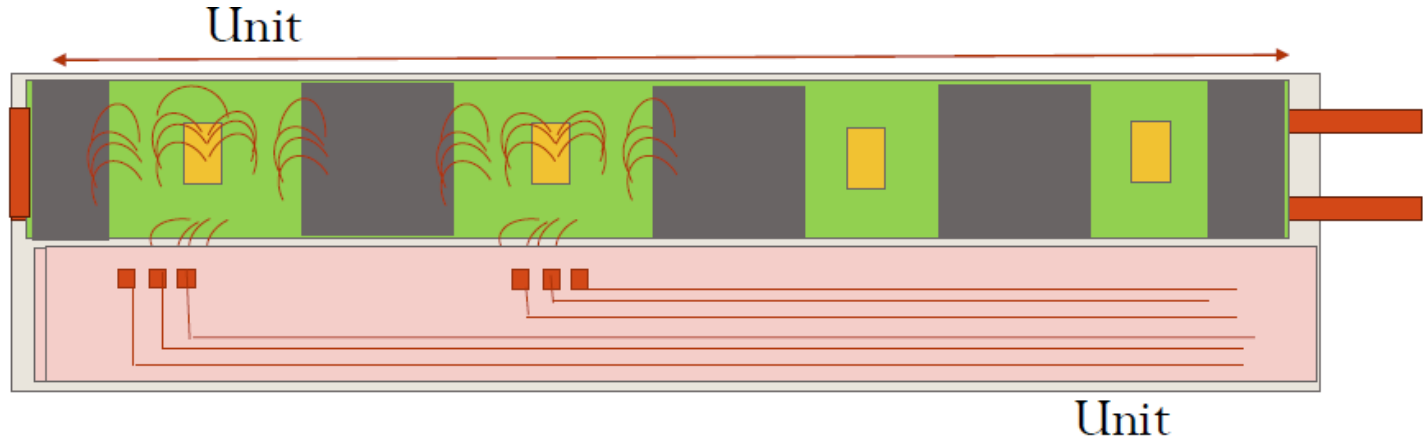
補助FPCをつかってブリッジする

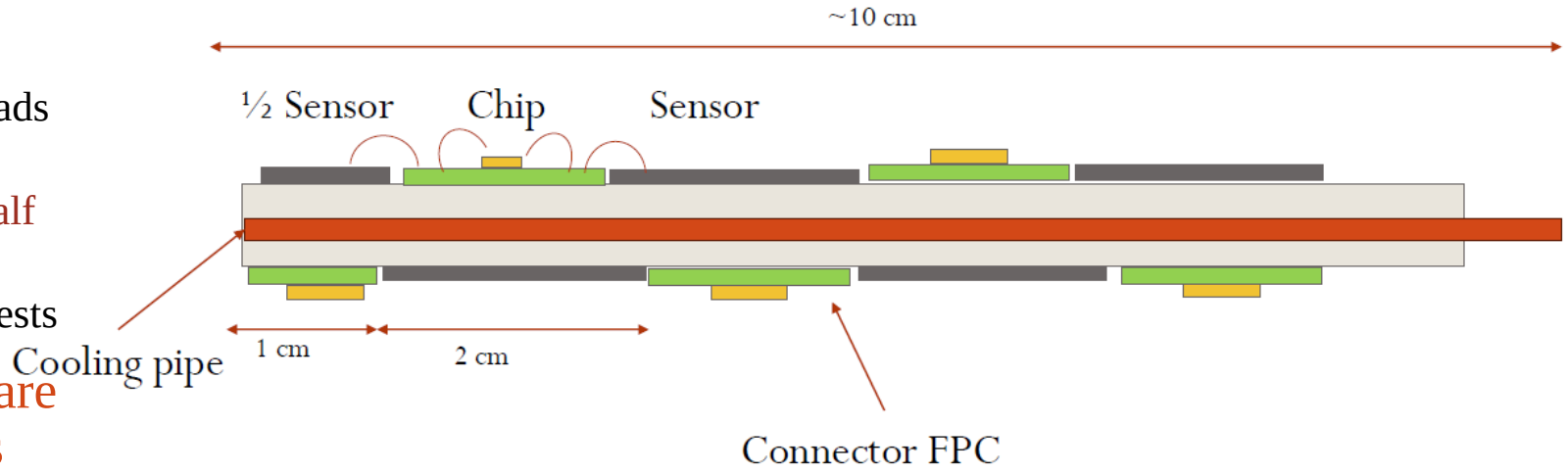
- TABボンディングの配置密度などの情報が必要

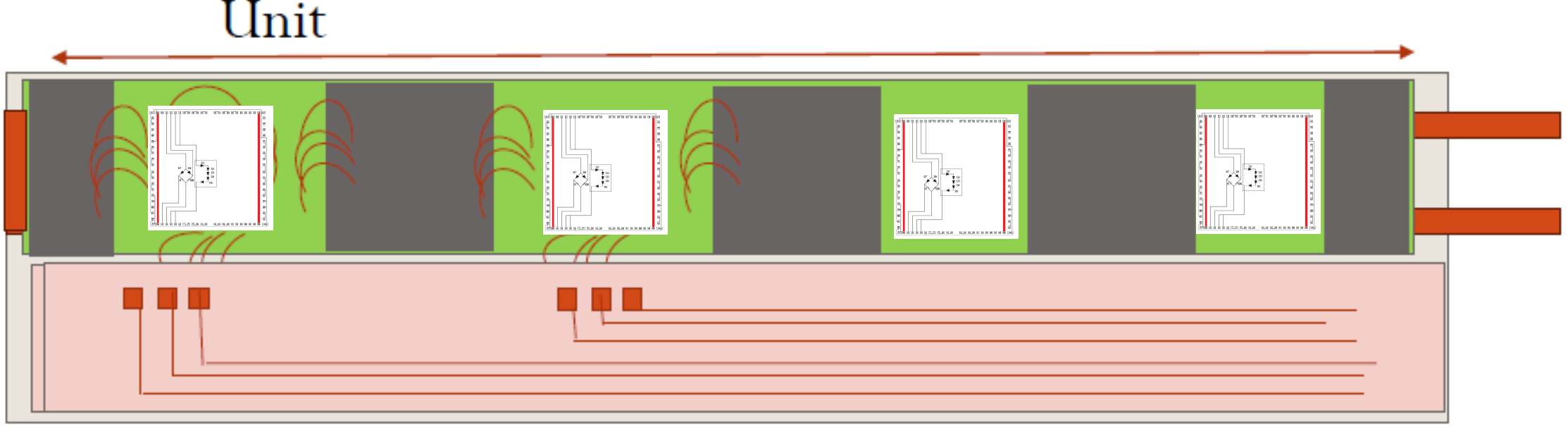
試作FPC

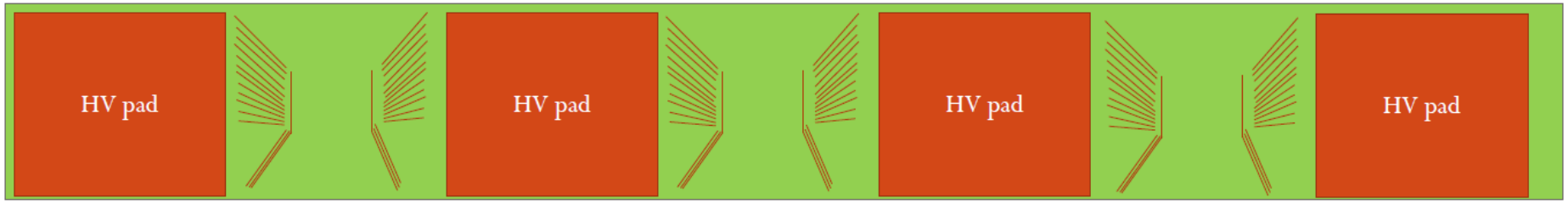
排熱テスト用試作機

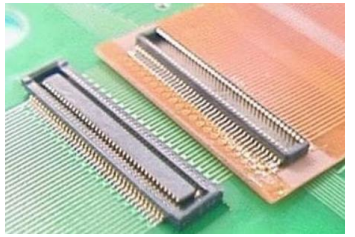
- ゴール:　実装＋排熱をテストする
  - 組み立て＋実装のテスト
  - 熱の逃げ道をみてみる
- 進め方:
  - パーデュ大＋ ORNL　：　ステーブ（構造材）＋　FPCとの張り合わせ
  - FPC from JAPAN (Takashi and so on)
  - UCSC will glue, verify positioning and wirebond sensors and silicon heaters
  - Heathers (1x1cm) have embedded temperature sensor and a series of bond pads to be paired with sensor.
  - Purdue or ORNL will assemble the two half staves with cooling pipe
  - UCSC will perform electric and thermal tests
- HPK sensors arrived at UCSC, many are NOT working, so ok to be used in this project



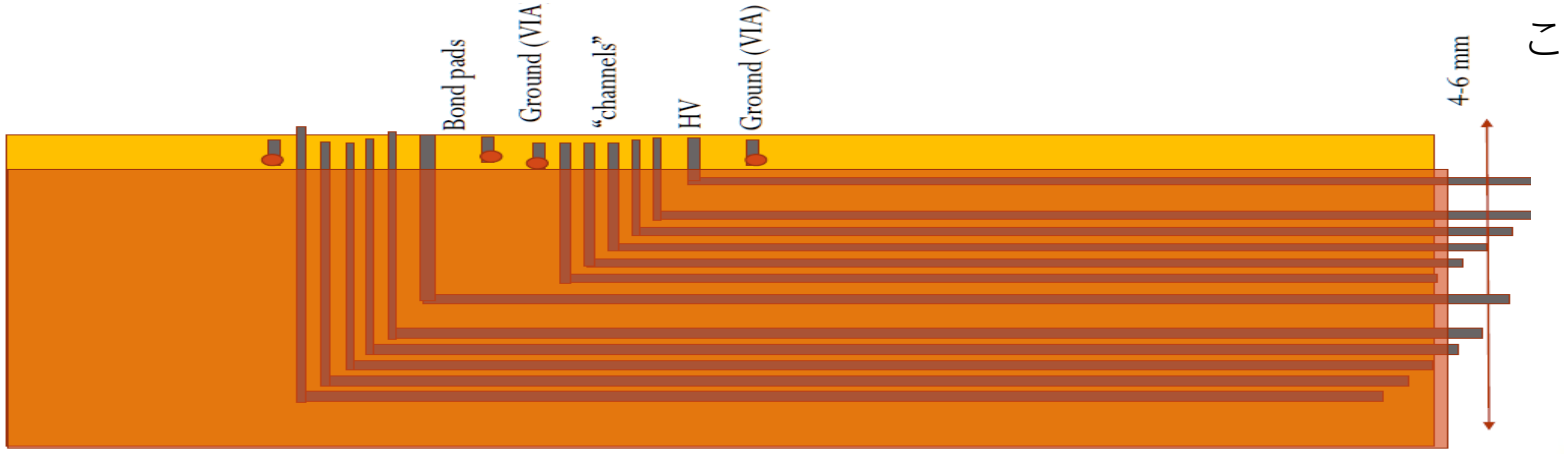


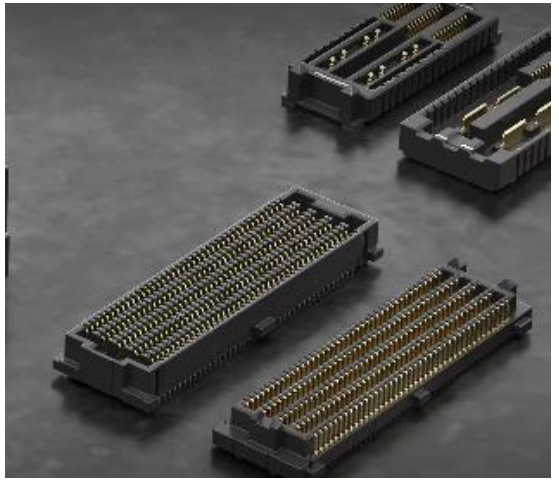


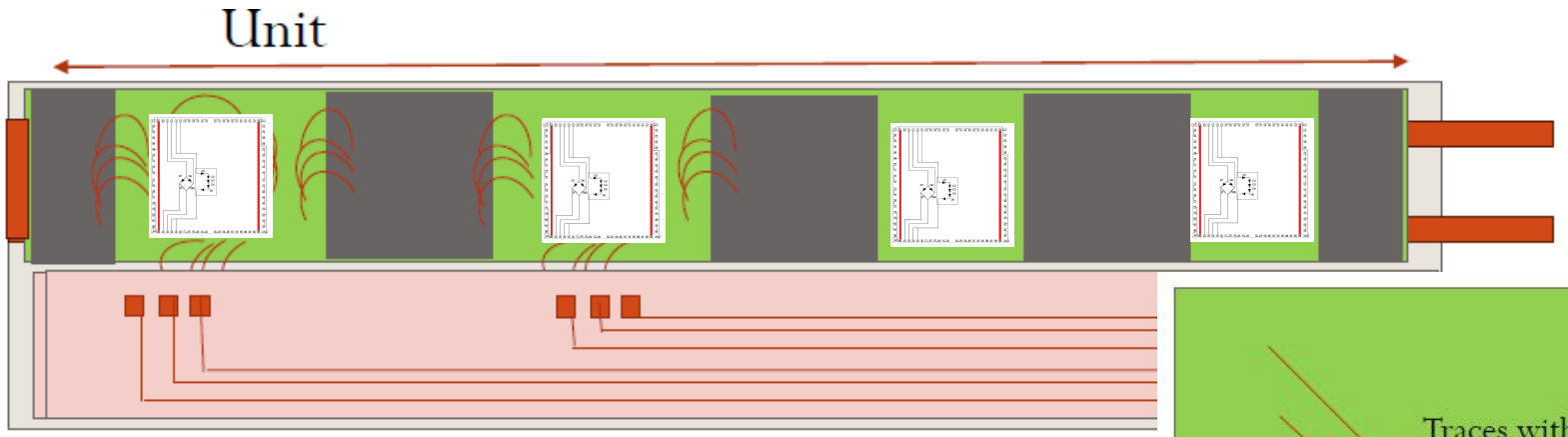


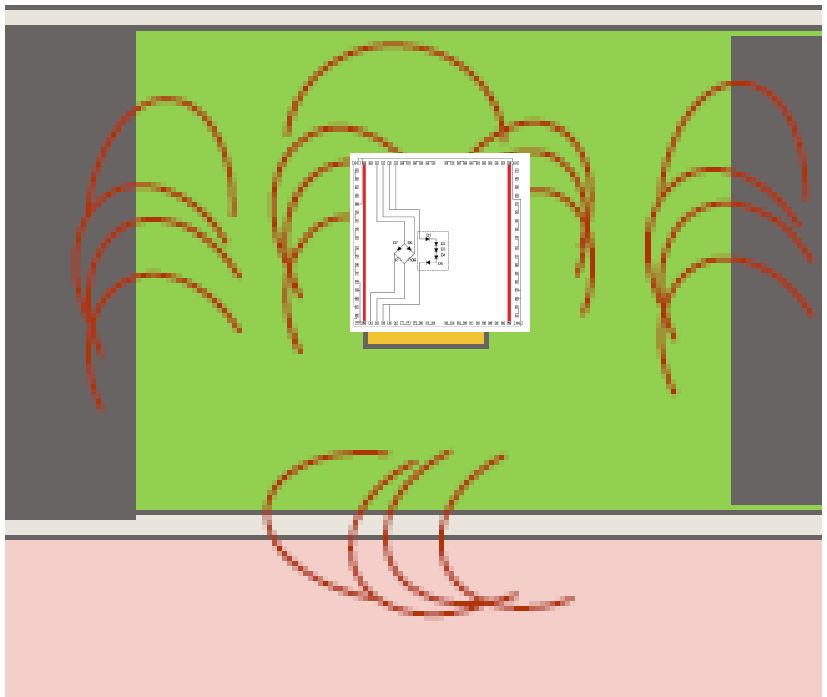


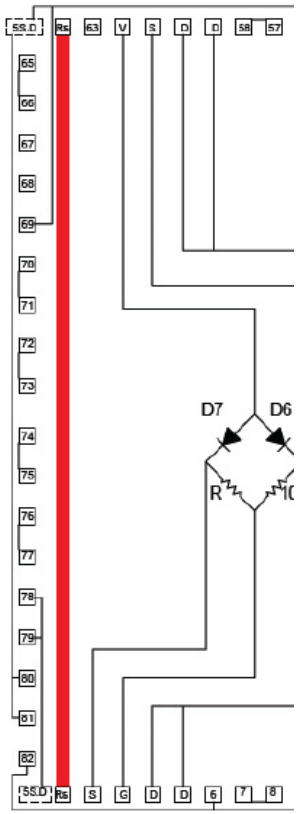
この端のコネクタをどうするか？

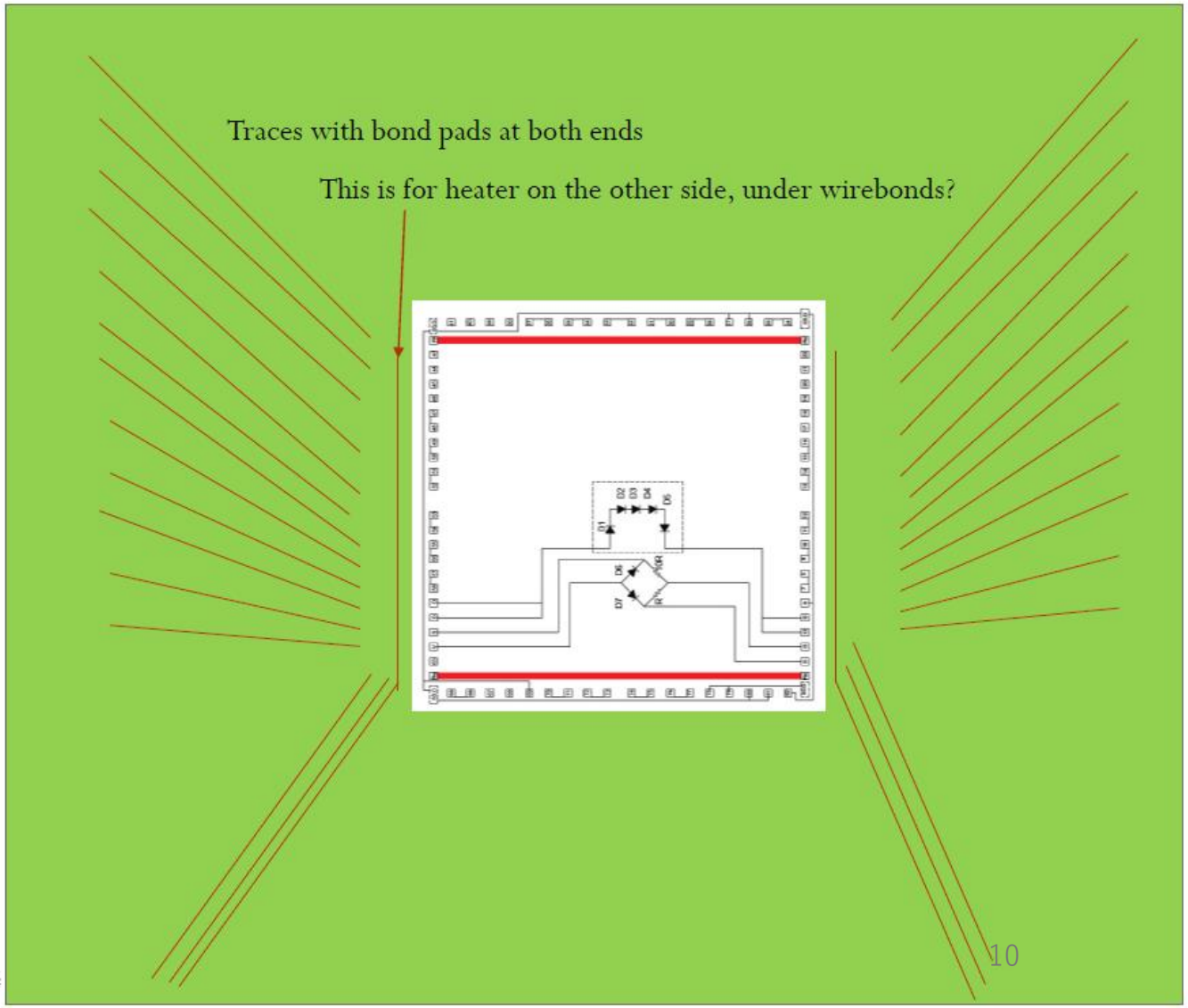


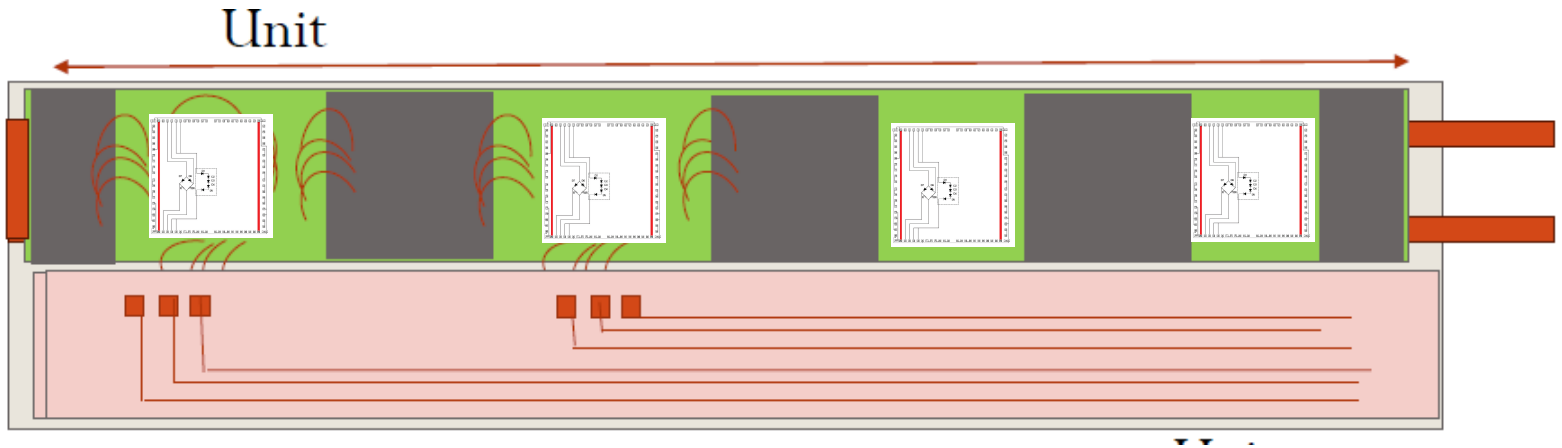


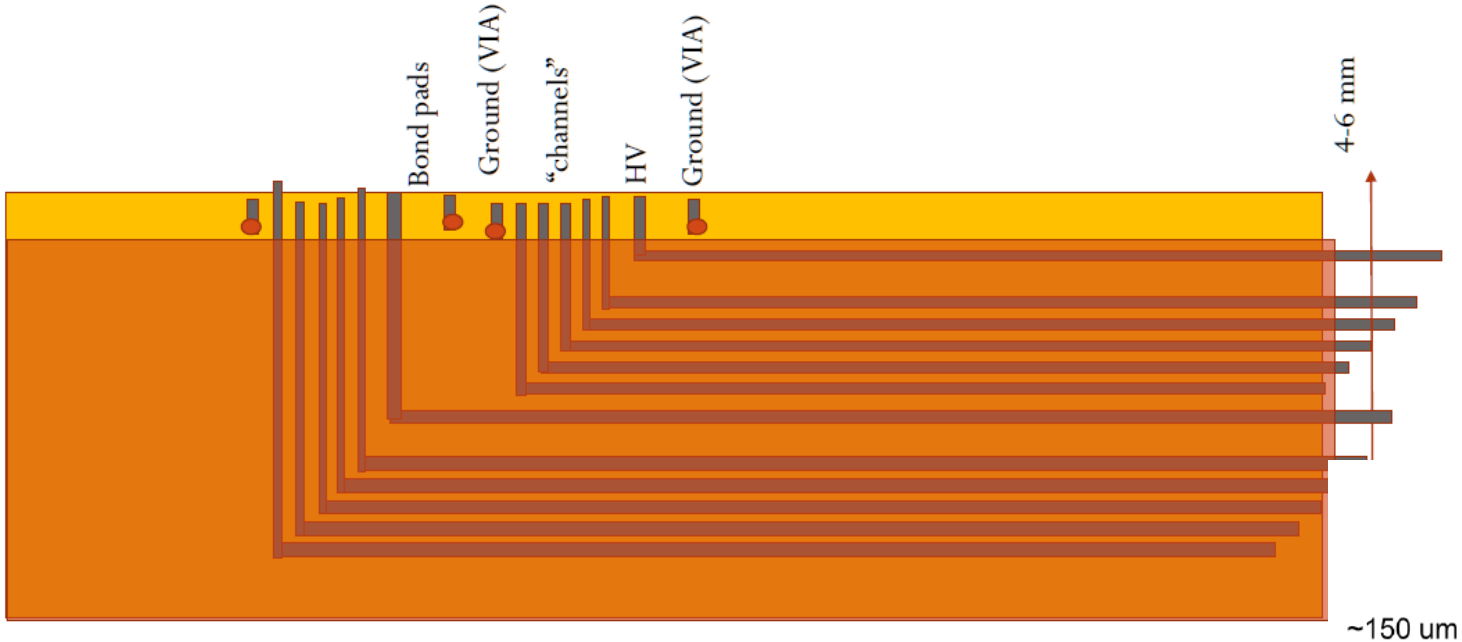

Unit

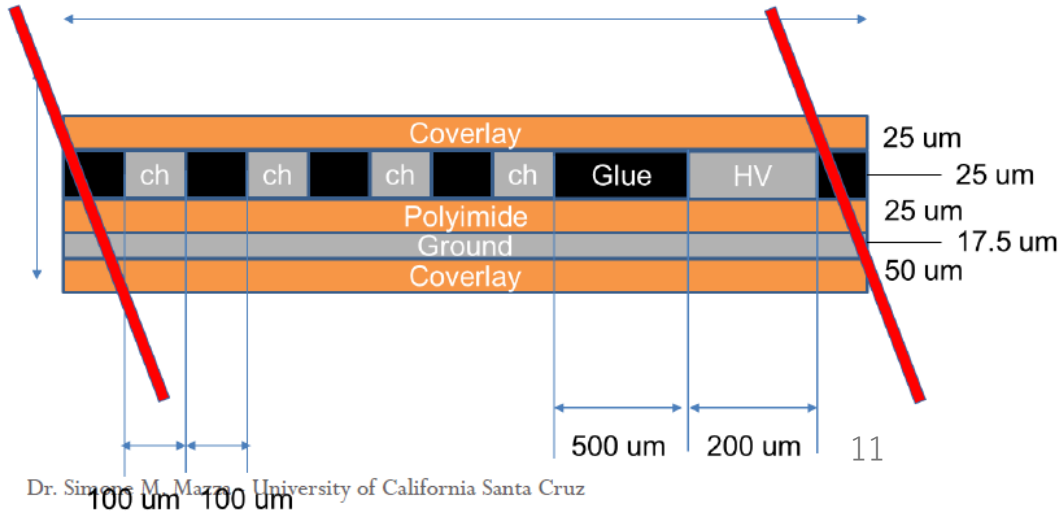


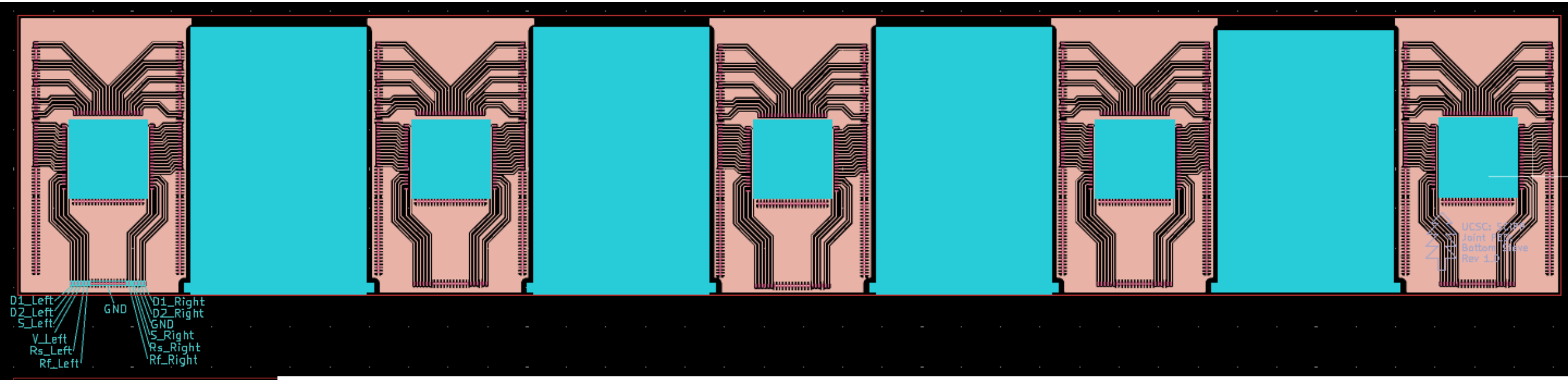

D7
D6

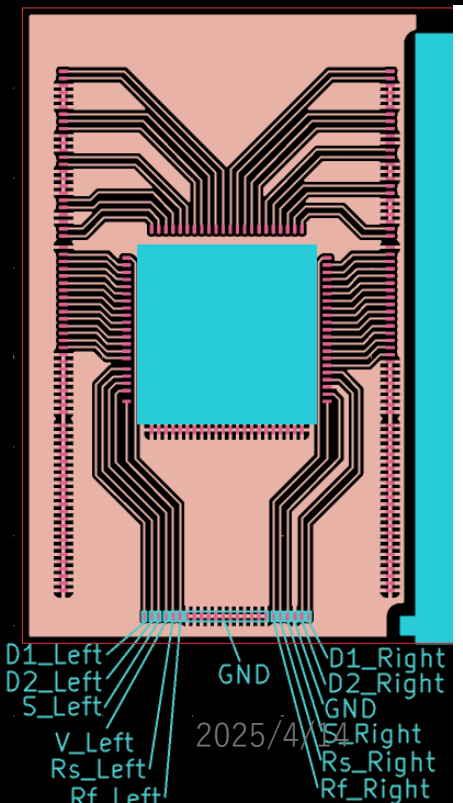

Traces with bond pads at both ends
This is for heater on the other side, under wirebonds?

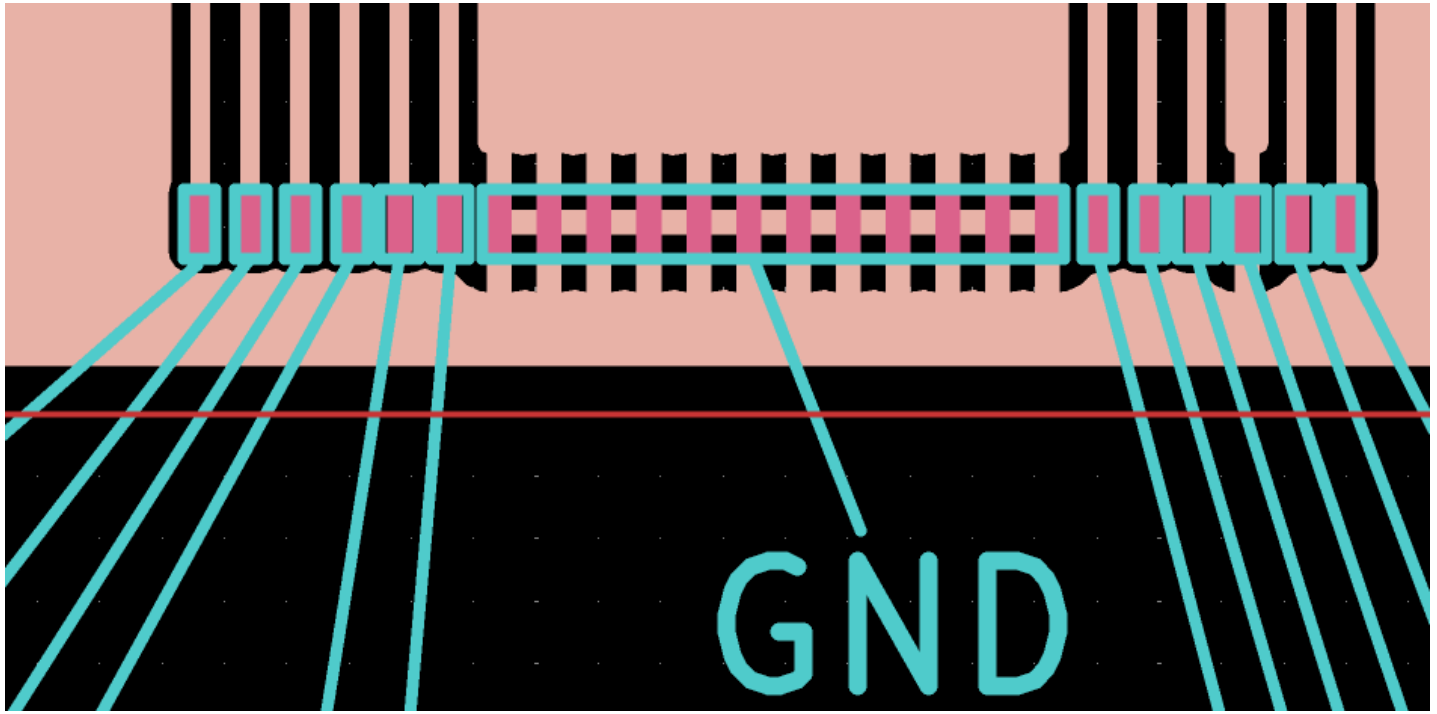

Unit


Bond pads
Ground (VIA)
"channels"
HV
Ground (VIA)
4-6 mm
~150 um

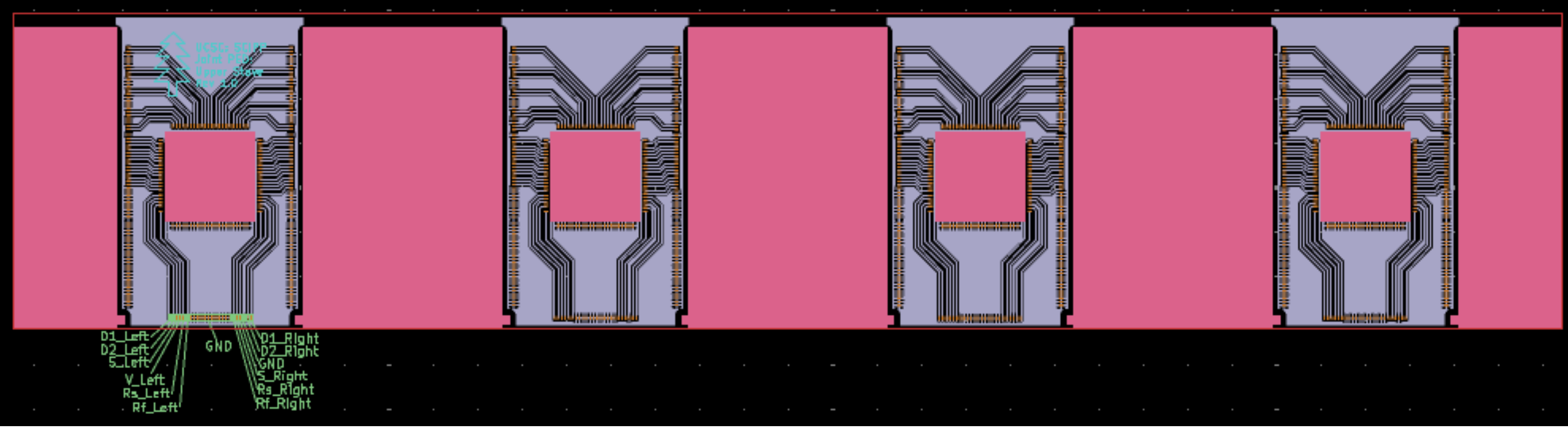

Coverlay
ch
ch
ch
ch
Glue
HV
Polyimide
Ground
Coverlay
25 um
25 um
25 um
17.5 um
50 um
500 um
200 um
100 um
100 um



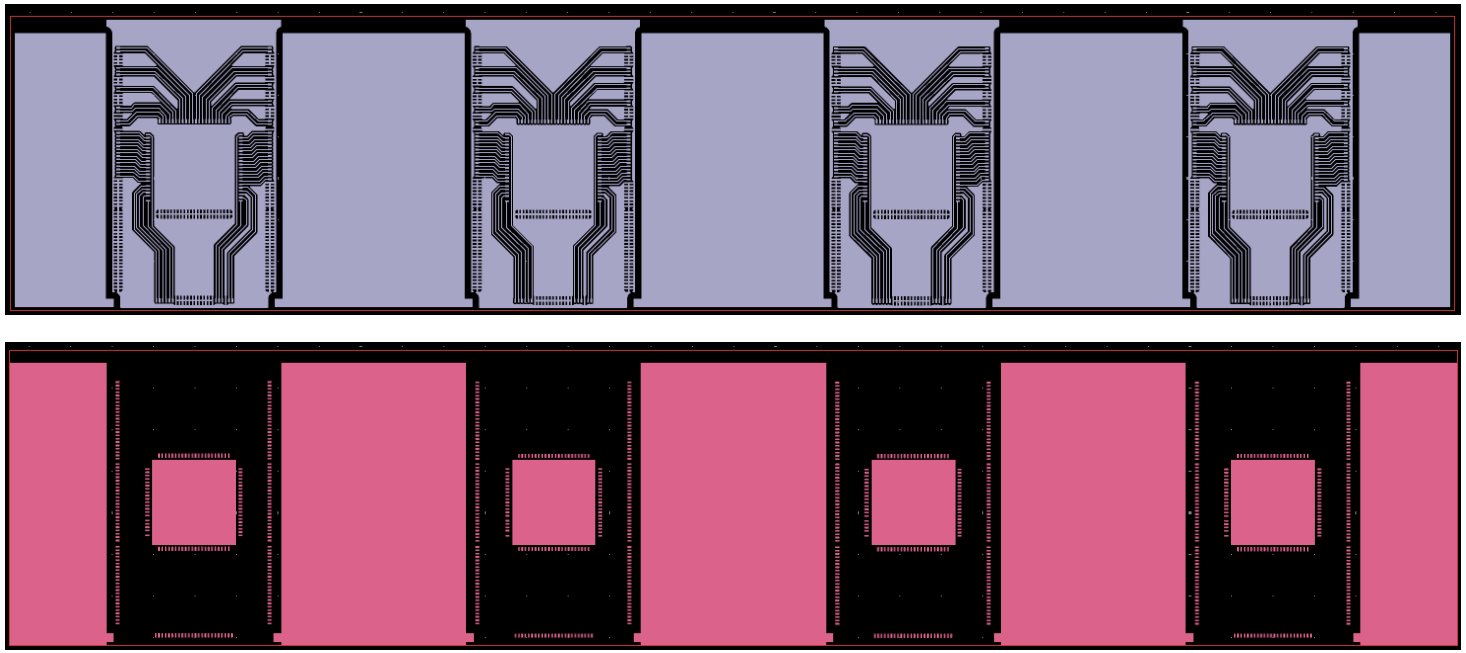




- ガーバーデータあります。


D1_Left
D2_Left
S_Left
V_Left
Rs_Left
Rf_Left
GND
D1_Right
D2_Right
GND
S_Right
Rs_Right
Rf_Right

- 裏面



スケジュール

- 次のCDのレポートに載せたい
- 製造まで数か月(6月頃？)
  - 蜂谷も予定を聞かれた(4月以降は可と返答)

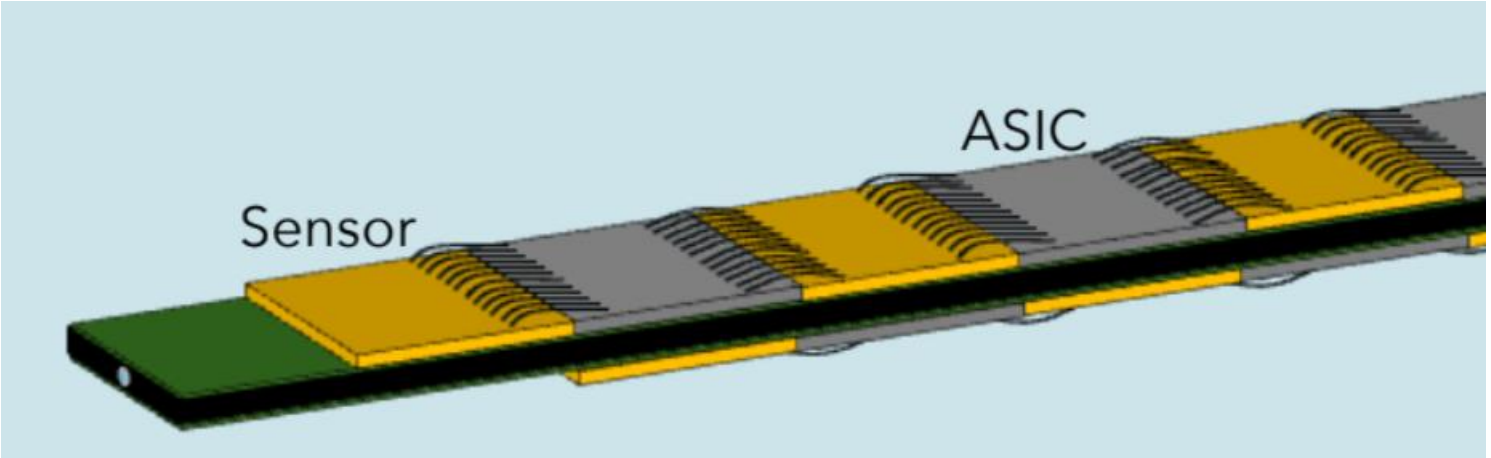
- FPC製造の不明点
  - 具体的はパッドの位置
  - 反対の端の扱い(コネクタ？)

相談したいこと

- 排熱テスト用試作機のFPCの設計と製造
  - 1～2か月。
  - 簡易で安く作りたい。

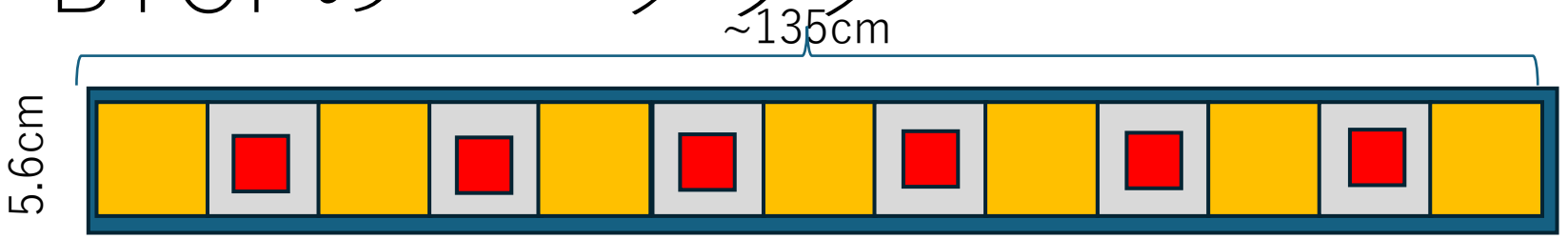
- BTOFラダー用FPC
  - そもそもできるのか？
  - 短いものをつなぐ方法を検討したい。

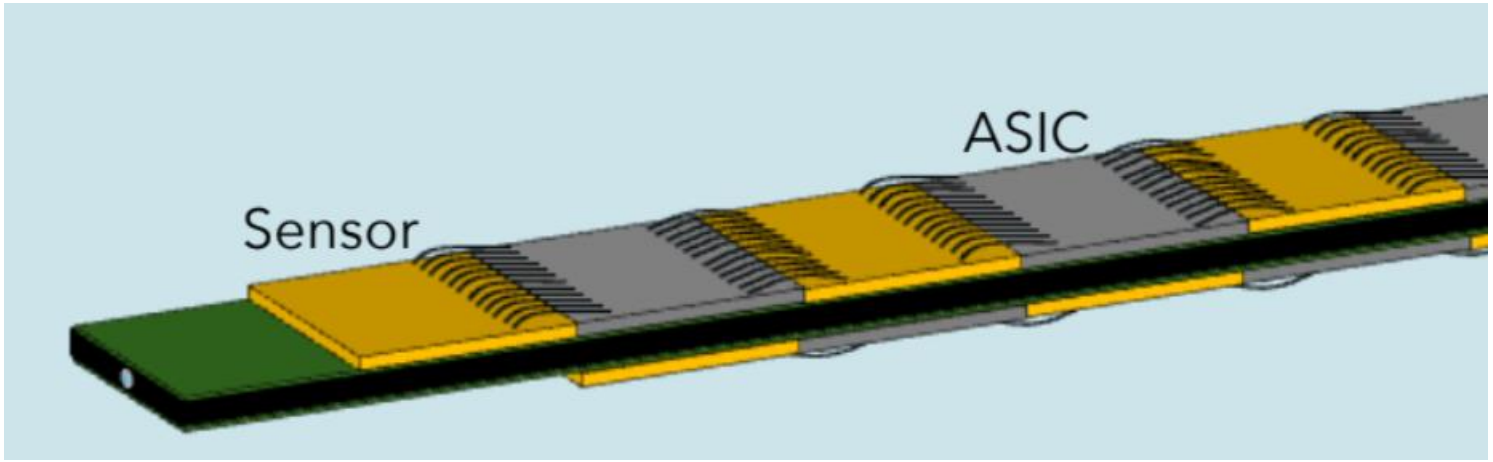
表裏にFPCを配置する例

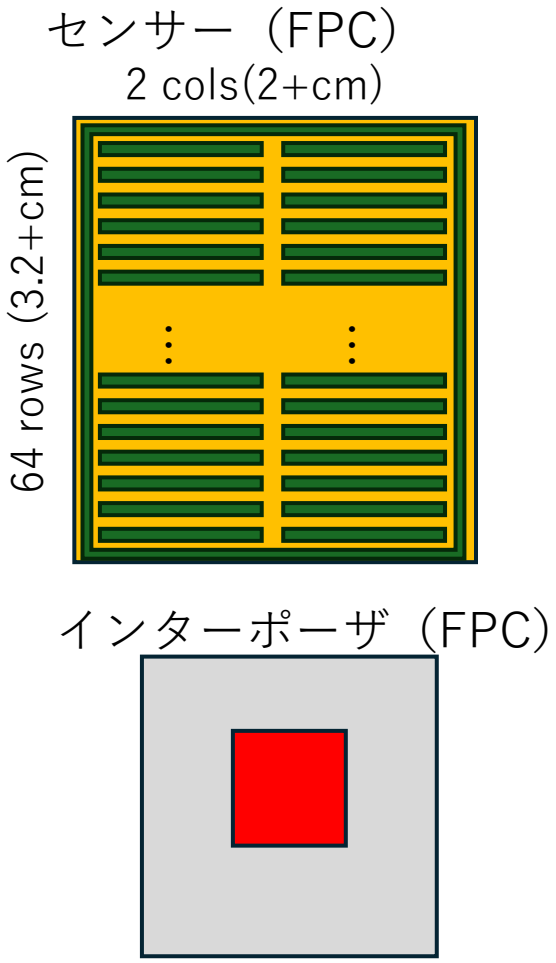


- Belle-IIのダブルサイドストリップ検出器
  - 折り紙接続が参考になるかも。

BTOFのハーフラダー

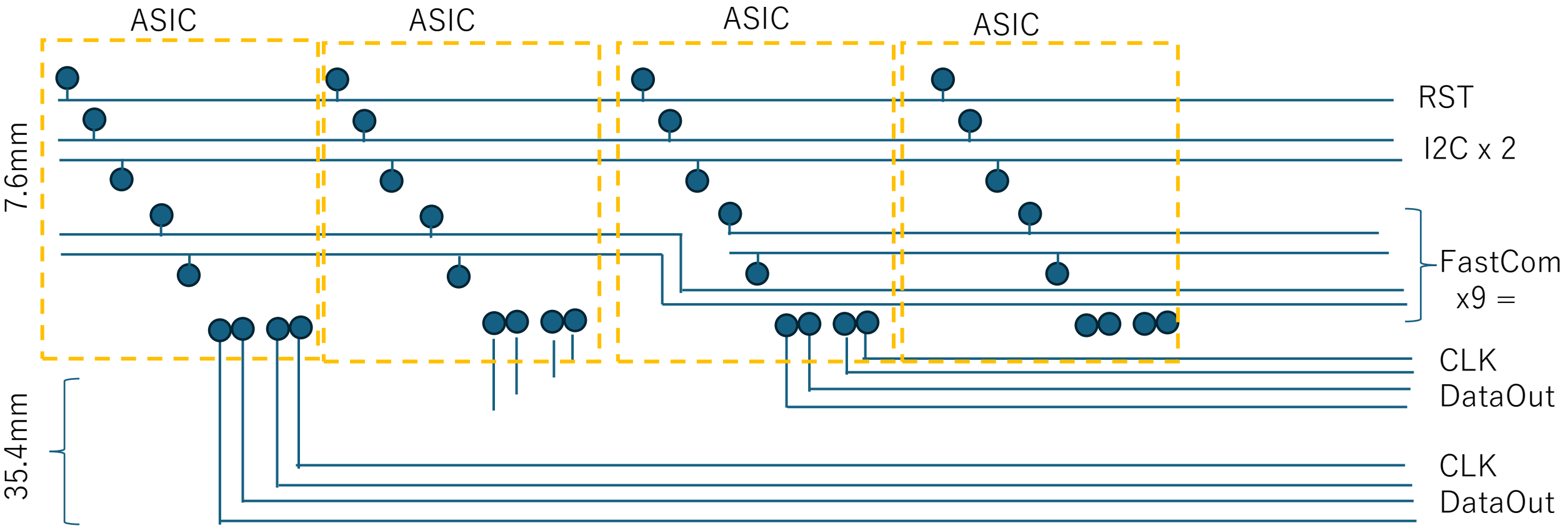






- 構造材を挟んで、表面と裏面にセンサー＋ASICを配置
  - FPCは両面に必要
  - FPC：**135cm　＋　コネクタ部**
  - **センサー：　3.2cm x 2cm x 34個 (33個)**
  - **ASIC(未定)：　既存のASICをBTOF用に改良予定**
  - **配線数：　～200 (34FPC)　　(INTTは124本)**

信号層を単層にする検討



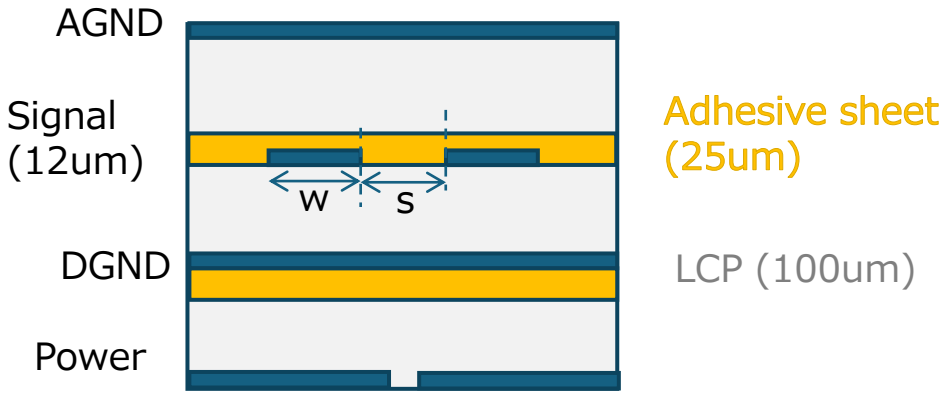
- バスエクステンダのデザインをもとに検討
  - Line (130um) + space (130um) + Land (for thru hole) = ϕ300um ~ 600 um
- Thru hole width : ~ 8.8mm (0.6mm*7+ 0.52mm*8 + 0.6mm = 4.2+4+0.6)
- Line area width: 34 * 4 * 260um = 35.4mm + アナログ配線
- Land for powers and GND are also necessary

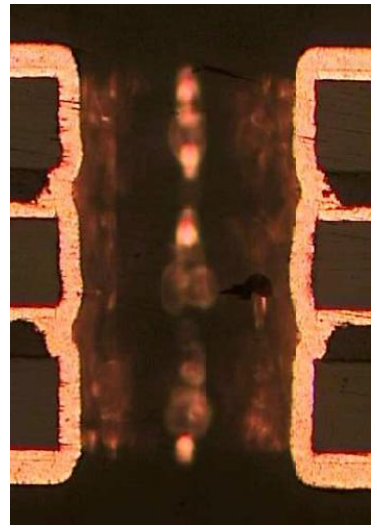
~44.2mm :
signal lines occupy < 5cm width

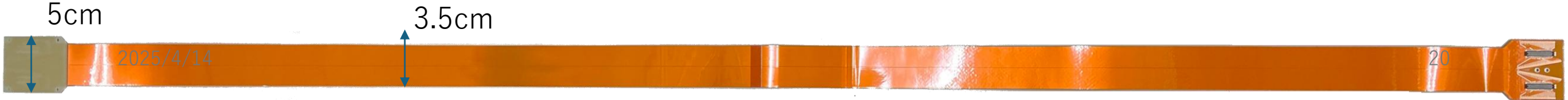
Long FPC from sPHENIX INTT

- Cable design (prototype)
  - Dimension (L x W): 130 x 5 cm^2
  - 4 layers (signal , 2xGND, PWR): X = 0.8% X_0
    - Cu : 12um thick per layer + 30 um Cu plating on surface
  - Lines : 124 lines (Line and space : 130 & 130 um)
  - Z_{diff} : 100Ω by strip line structure
    - Signal layer is sandwiched by GND layers
  - Liquid Crystal Polymer (LCP) as substrate
    - Less signal loss due to low di-electric constant & tan(δ)
    - Thick LCP available for Z_{diff} : 100um

4 layers laminated by the adhesive sheet



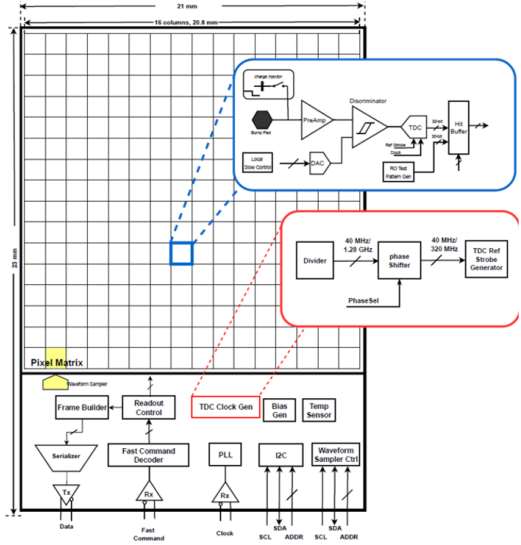




Signal lines based on ETROC2

- Size : 21x23mm^2 (Box shape) since 2D for the pixels
  - Bump bonding for pixel (CMS)
- Npads : 124 w/ wire bond
  - CMS Digital lines: 13 lines
    - Tx: 2x DataOut (DS)
    - Rx: ***CLK40 (DS)***
    - Rx: ***FastCom (DS)***
    - Rx: **I2C (2 lines, SCK, SDA)**
    - Rx: **RSTn (1 line)**
    - Rx: I2C addr (5bits)
  - Analog : 1 line (Vtemp)

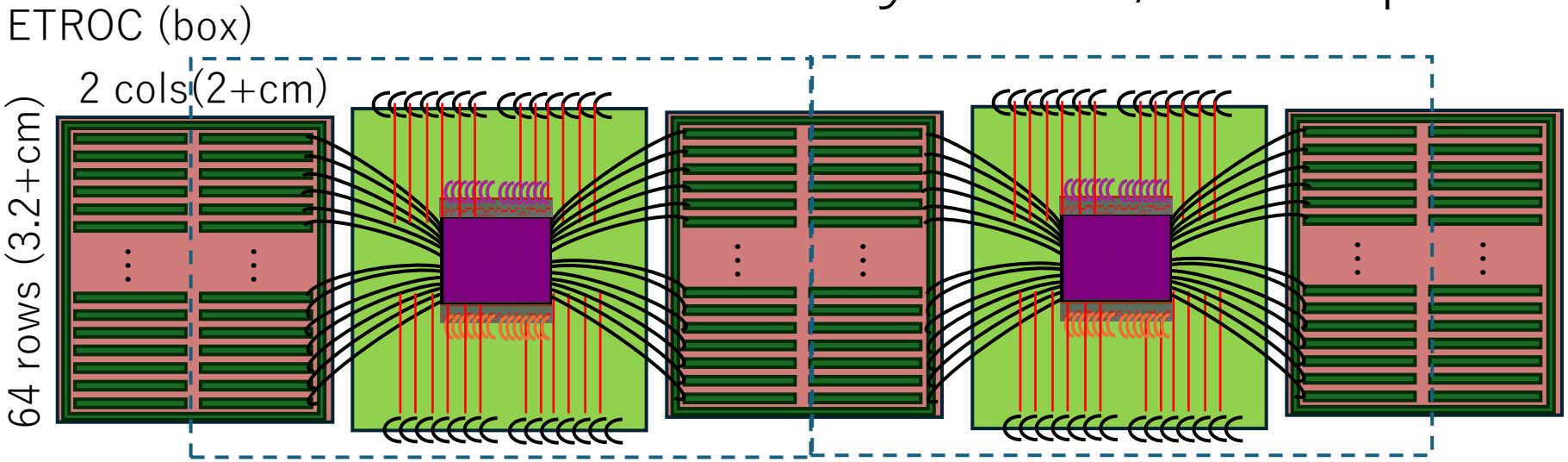
ETROC for BTOF FPC
→ BTOF FPC ~5 or 6 lines
→ 1x DataOut (DS) = 2 lines
→ ***p2p = 2 lines***
→ ***bus w/ 4 chips (not p2p) = 2 /4 lines***
→ ***bus w/ 17 chips = 2/17 lines***
→ **bus for all chips = 1 / 34**
→ 5 or 6 bits (depending on FPC conf.)
→ ***1 line***



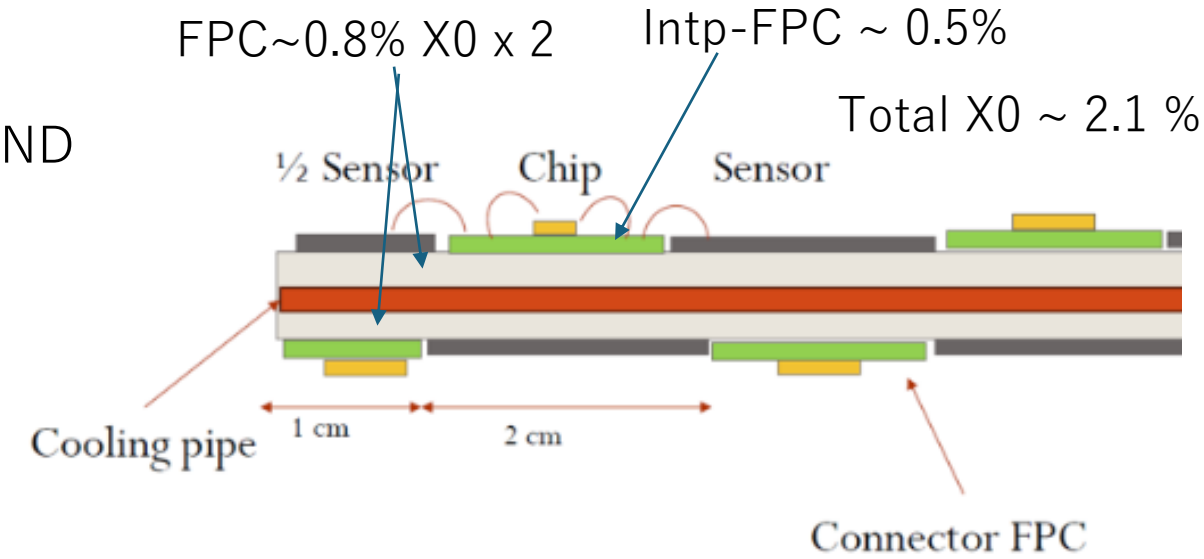
https://etl-rb.docs.cern.ch/Specifications/etroc-test-card/#Specifications

- 135 cm FPC = 33 or 34 ASICs/FPC (x2 FPC x 2cm/sens)
  - **33 or 34** sensors are necessary
- If 34 ASIC's are in a FPC, 34 x {4 + 2/4+ 2/17 + 1/34+1} = 194 lines in total
  - INTT: 124 lines w/ 3.5cm width (1.5 times more than INTT,)
  - If use INTT technology, Thickness is ~0.8 % X0 / FPC We use 2 FPC for a ladder ~ 1.6%X0

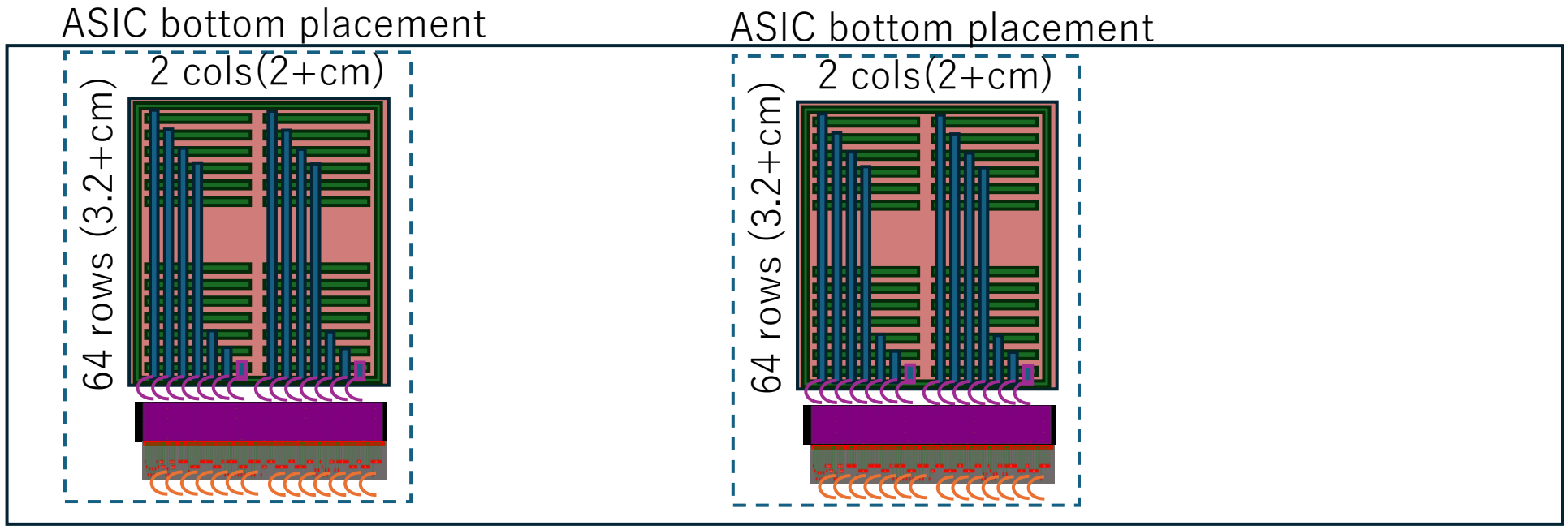
Sensor and ASIC Layout w/ interposer



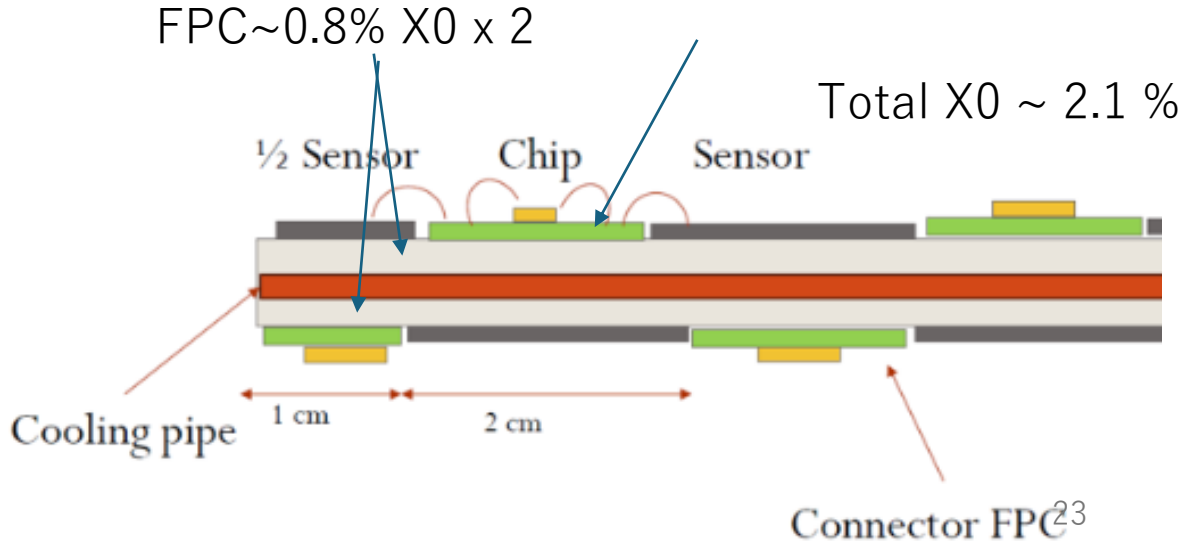
- Interposer FPC (green)
  - Routing signal lines from ASIC to FPC
  - Multiple (2~3) layers needed for DIO, power, GND
    - Additional thickness >0.5 % X0 -> Total~ 2.1% X0
  - Length of lines could be different
    - may get the time resolution worse
- Sensors & ASICs are connected
  - Difficult to make a (simple) module structure



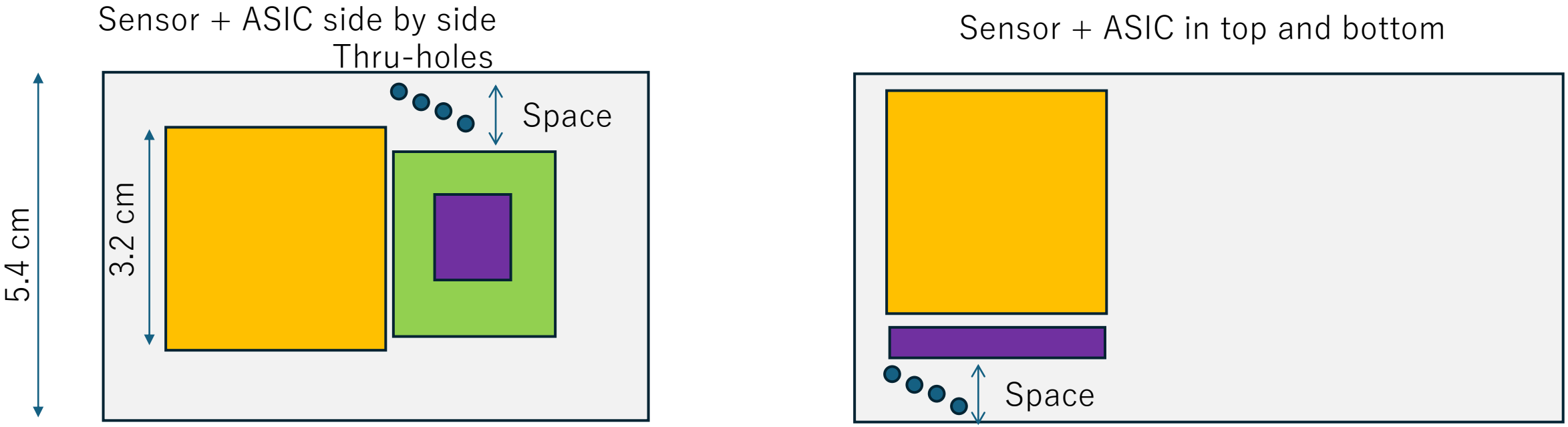
Option : Bottom layout of Sensor and ASIC



- ASIC at Bottom
  - Easy to make a module
  - Different lengths of double metal
    - Signal might be distorted
  - Simpler wire bonding
- If interposer, routing the lines get easier



Space btw FPC and ASIC needed for wire bonding



- How much space is necessary to come out the signal lines from inner signal layer

Short FPC option

- Ladder : 135cm long with 34 sensors and 34 ASICs

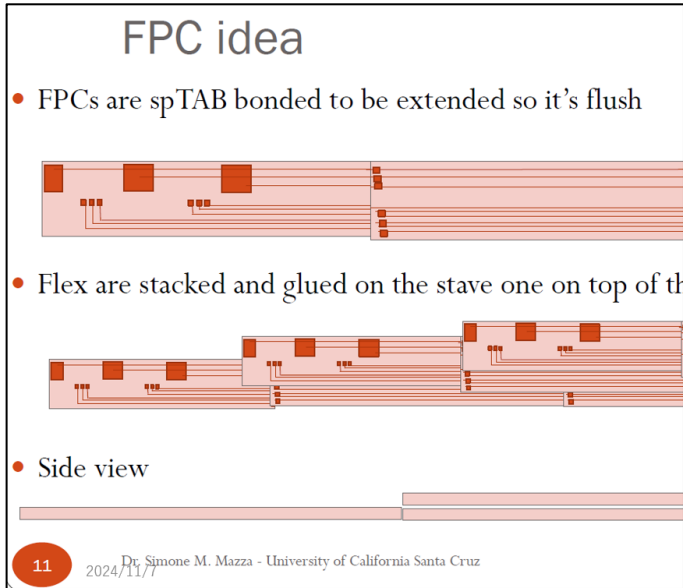
  - Minimize the additional connection
  - Assembling this very long module is difficult
    - Yield rate will be issue during the production

- If split by 3 pieces, each FPC is 50cm long

  - 50cm FPC can be made with minimum risk in production
    - Finer line & space available (60um x 60um)
  - Multiple connection needed
    - Reduce active area by connecting these FPCs

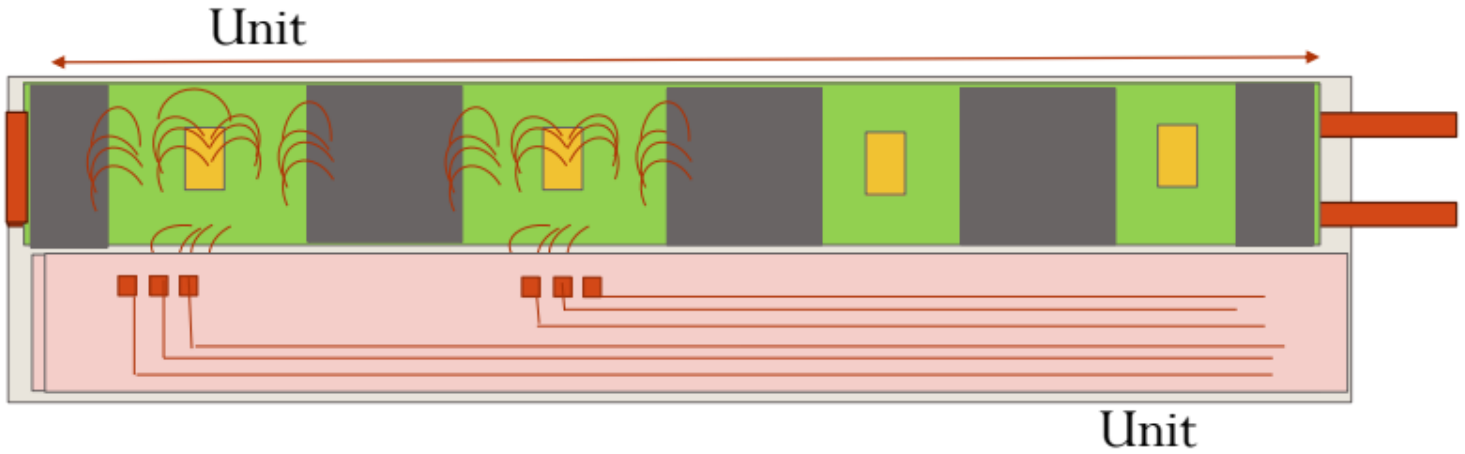
- How connect each other ~ 200 lines + power + GND
  - spTAB bonding
  - Connector (micro pitch)
    - Fragile, (not so reliable?)

Simone's slide in Nov. 2024



Double-sided stave

- Issue with small units: doubles the number of ASIC
  - I we do large units with half-sensors at the edges the number of ASICs would stay the same and it can be assembled 'stand-alone'
  - Demonstrator can be one unit length ~16cm



- Same number of ASIC but introduces small 'gaps' (~1mm) between units
- Other stave side will have an ASIC in that position