Barrel Time-of-Flight

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Readout board for sensor test status

- UCSCの設計をベースとしたRDOの基板設計は完了by金田さん
  - 16チャンネル読み出し。センサー下部に穴
- 基板は発注まだ。このあとするby八野
- 設置するパーツは発注済みby八野
- 歩留率が向上したセンサーが浜ホトから提供
  - 33 x 22 mm^2 サイズ（1mm, 0.75mm, 0.5mm pitchが混在）
  - 30um x 14枚、50um x 14枚（たぶん全部うごく。青嶋さんに確認中）
  - こういうのを管理したい。理研？広島？
- 九州大学（東城さん）からのワイヤーボンディングの支援あり
  - 共用機器使用の技術指導含めた全面的サポート（利用料金は払う）
  - ワイヤーボンダーマシン選定に関する打ち合わせを提案してくれている
    - 日程はまだ。でも早急に決めたい。関係する人みんなで九州へGO。

IR Laser system

- UCSCとBNLが使用しているTCTシステムの会社から返信があった。
  - Scanning TCTとLarge Scanning TCTの2種類ある
    - Large Scanning TCTの方が可動域が大きく、マウントできる重さも大きい
  - 基本システム：
    - レーザー、照準光学系（走査ステージ含む）、ソフトウェア、環境モジュール、センサーマウントステージ、保証1年
  - 基本システムの値段
    - Scanning TCT：21,500€
    - Large Scanning TCT： 25,300€
  - オプション：
    - ビームモニター：2,500€
    - ビーム観察用顕微鏡：1,000€
    - 高電圧電源： 1,300€
  - 購入するならLarge Scanning TCT＋ビームモニター＋ビーム観察用顕微鏡： 28,800€→4,600,000円くらい
  - 付属しているレーザーの問題点：位置分解能は11umあるが、時間分解能（jitter）が不明（今問い合わせ中）
    - （先週八野が350psといったのはpulse widthでjitterとはまた別のパラメータ）

納期3ヶ月

- 中村さんが提案してくれたレーザー（jitter<10ps）は製造中止
  - HKT ONEFIVE KATANA pulse lase
- 代替品レーザーをHKTの日本での代理店であるセブンシックス株式会社にお願いしている
  - HKTは浜松ホトニクスに買収されており、浜松ホトニクスは我々が何をしたいか知っているので彼らに聞いた方が早いかも

ePIC TOF Open Questions

- These slides are intended to document open questions that are creating bottlenecks to advancing the TOF barrel and forward technical design and integration.

- They are not the only open questions!
  - These are the questions that are the immediate show-stoppers and must show progress in the next few months
  - Short-term focus required to resolve these questions

Open Physics/Simulation Questions

- What is the required physics performance for the barrel and forward TOF?
  - How much of an overlap is required with the hp-DIRC and dRICH (aerogel) for 3σ e-π, K-p, and π-K separation
    - This should be set by the overlap required to cross-calibrate the detectors
  - In combination with the start time resolution, this sets the TOF timing resolution requirement. This logic needs to be documented for the preTDR

- Does the 500μm pitch in the forward TOF contribute to the tracking resolution?
  - If not then the pitch should be reconsidered to reduce complexity and services requirements, optimize detector for PID only

Open Technical Questions

- Will the barrel TOF staves be “monolithic” or modular? If modular, at what level?
  - Consider anticipated losses/servicing/rework during construction
  - Serviceability for the detector lifetime is a key issue - this may drive/likely drives to modular.
    - This will impact performance and cross-correlates with open physics/simulation question
    - A decision is needed asap as it is correlated with serviceability of other detector inside the barrel TOF.
  - Reducing the material budget below what is required does not help if it makes the detector difficult to build and maintain

- Need a mechanical design for the forward TOF disc
  - Important to be able to plan integration and services

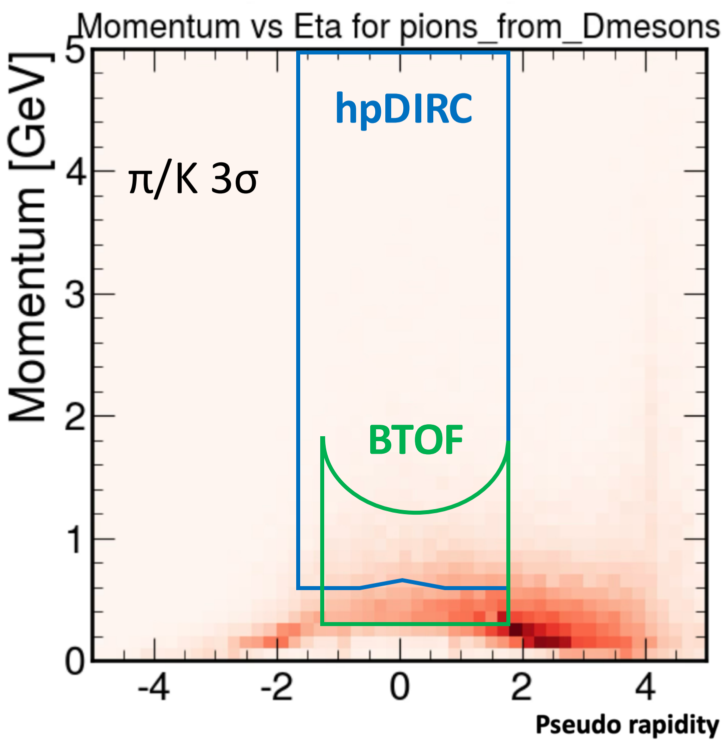
DSC Coordination and Meetings

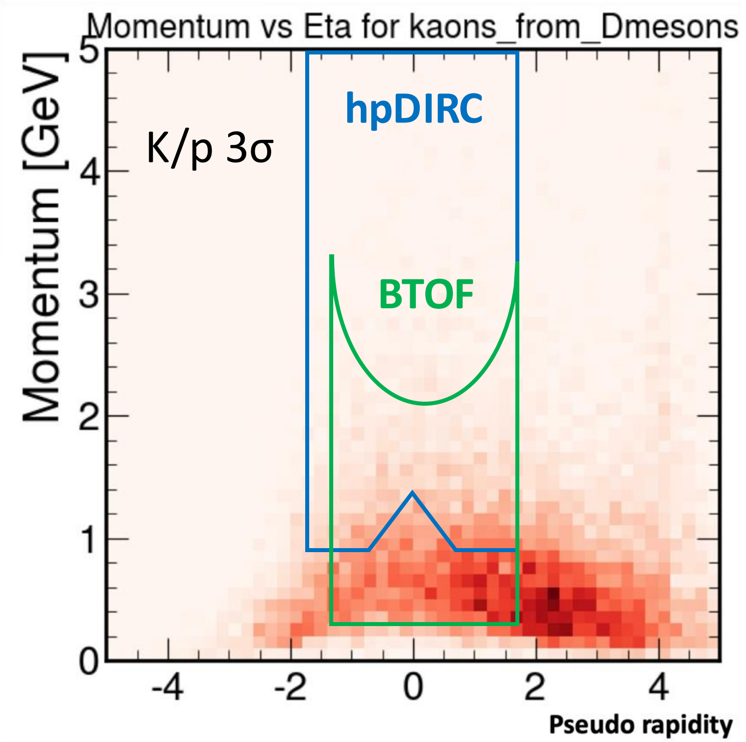
- To expedite technical progress and finalize the design phase, find a regular meeting time for the foreseeable future for DSC and ePIC leadership along with relevant CAM/project management to ensure priorities are clear and met in a timely manner.

- Is there a better schedule of DSC weekly meetings that will make it easier for more people to participate and communicate?
  - Overlap between sim/physics and technical?
  - Make it easier to engage and integrate new workforce

Importance of TOF at ePIC

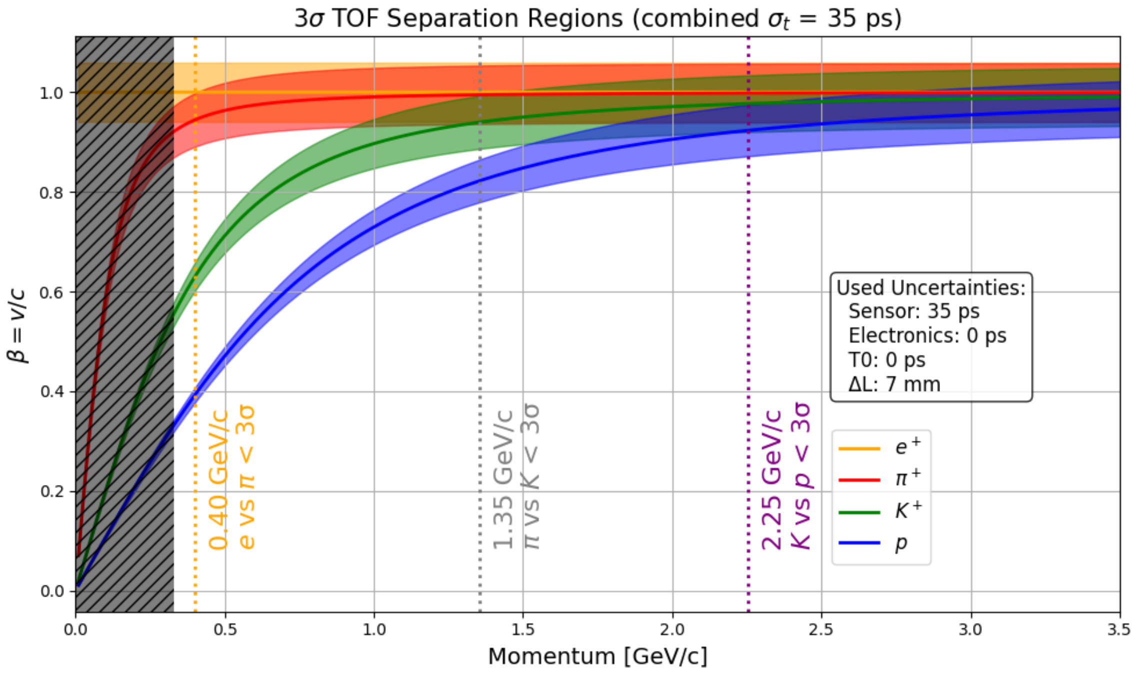
- HF measurement is the most important subject at EIC
- Decay products, π and K, from HF hadrons are mainly distributed in TOF region
- Light hadrons can be expected to be distributed over a lower momentum region

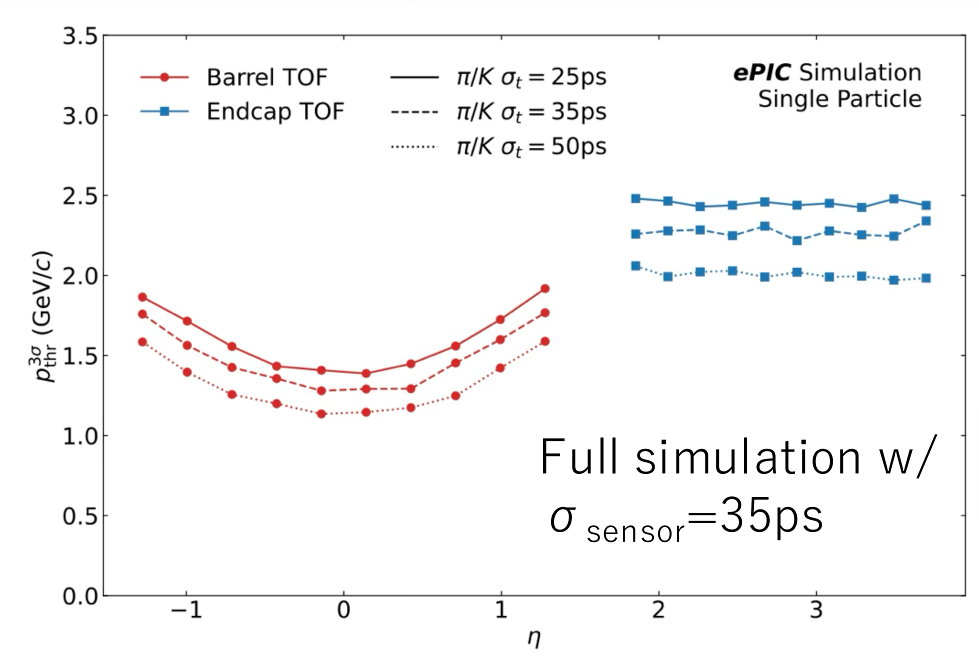




ΔL calibration

- The right panel simulation contained only the σ_{sensor} and ΔL
  - (If I remember correctly,) this plot is calculated full tracking simulation + smeared hit timing which means $\sigma_{electronics}$ = 0 and σ_{T0} = 0
- The performance of $p^{3\sigma}_{thr}$ = 1.35 GeV/c (η=0) when σ_{sensor} = 35ps can be described with ΔL~0.007m (σ_L~ 1.1% @ 0.64m)

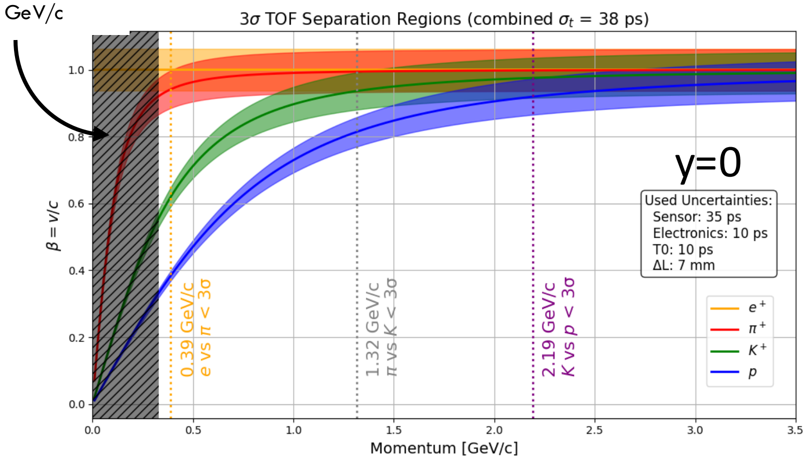




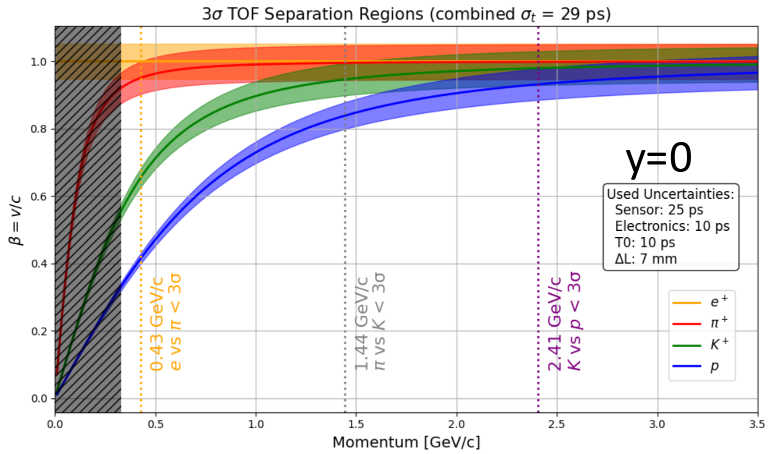
Beta v.s. σ_{total} (y=0)

Default Case (σ_{sensor}=35ps)

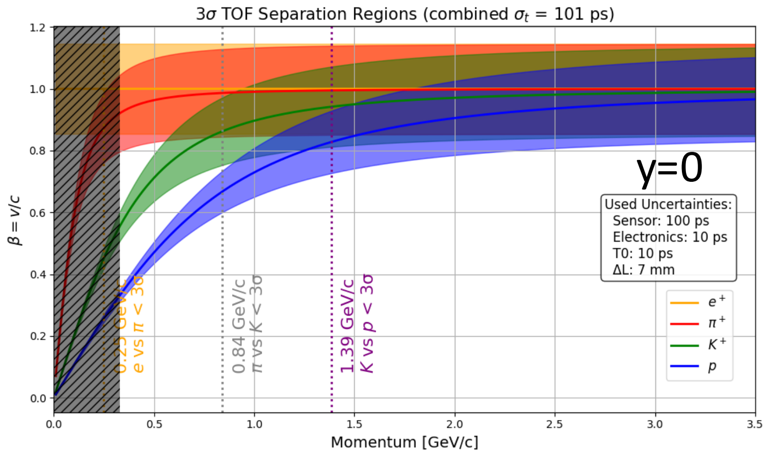
Not reaching BTOF
$p < 0.33$ GeV/c



Better Case (σ_{sensor}= 25ps)

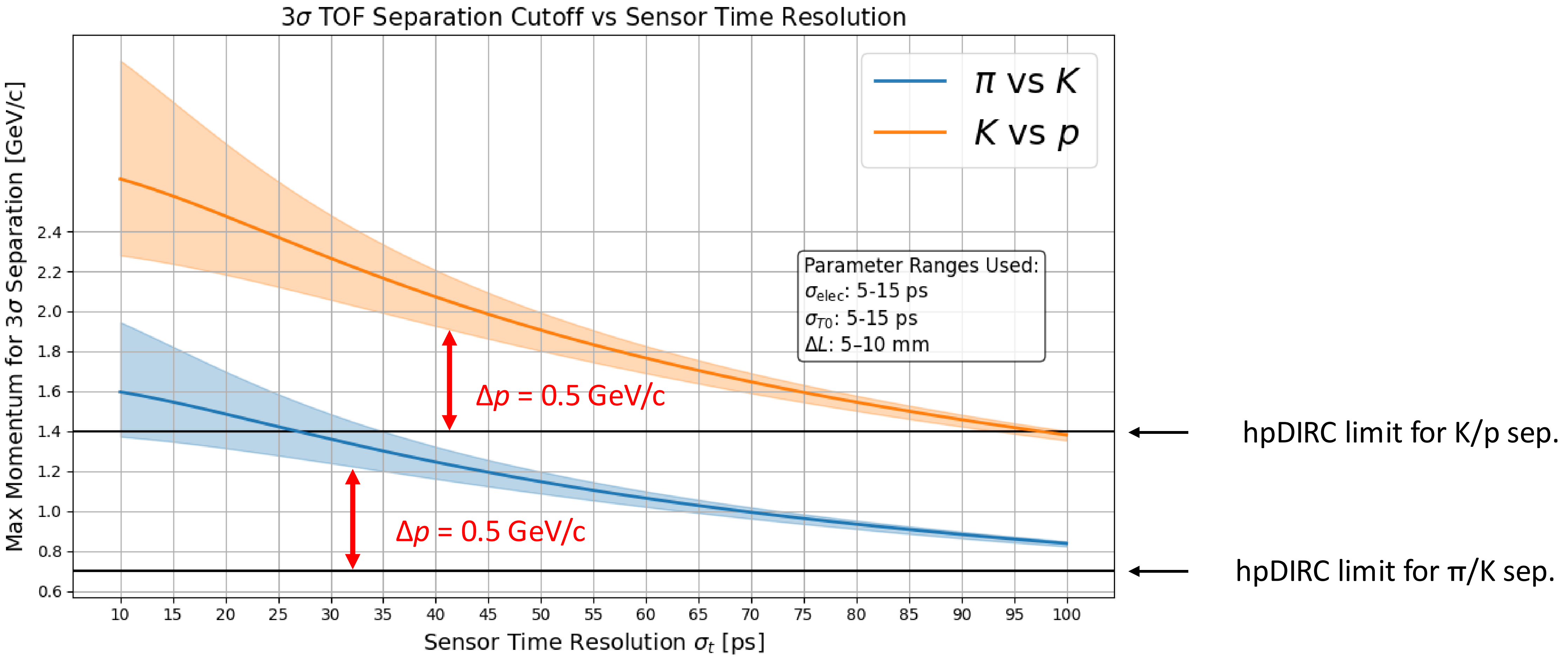


Worst Case (σ_{sensor}= 100ps)



- Some resolutions: σ_{ele} = 10 ps, σ_{T0} = 10 ps and σ_L = 7 mm
- Default case: σ_{sensor} = 35 ps (σ_{total} = 38 ps)
  - pion/kaon overlapping 0.7<p<1.32 GeV/c, Kaon/proton overlapping 1.4<p<2.19 GeV/c with hpDIRC
- Better case: σ_{sensor} = 25 ps (σ_{total} = 29 ps)
  - pion/kaon overlapping 0.7<p<1.44 GeV/c, Kaon/proton overlapping 1.4<p<2.41 GeV/c with hpDIRC
- Worst case: σ_{sensor} = 100 ps (σ_{total} = 101 ps)
  - pion/kaon overlapping 0.7<p<0.84 GeV/c, NO overlapping for Kaon/proton separation with hpDIRC

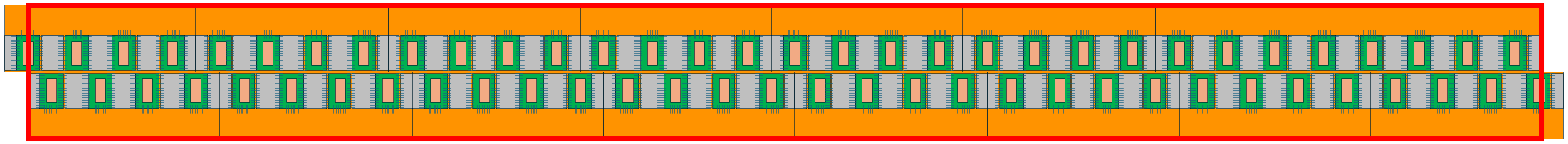
3σ separation v.s. σ_{sensor}



Considering the worst case (σ_{elec}=15ps, σ_{T0}=15ps, ΔL=10mm),
32ps sensor timing resolution is required to be 0.5 GeV/c overlapping for π/K separation

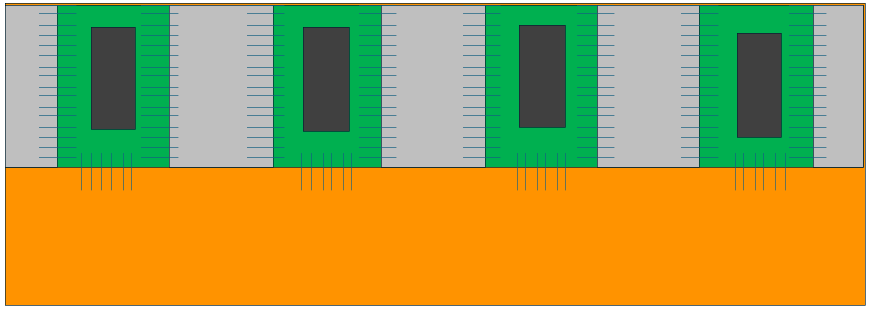
Stave Structure (Modularization ver.)

Half-Stave = 1408 [mm]

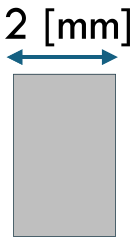


Acceptance = 1386 [mm]

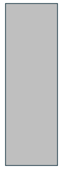
Module (Stavelet) = 176 [mm]



x 8 x 2 x 288
=4608



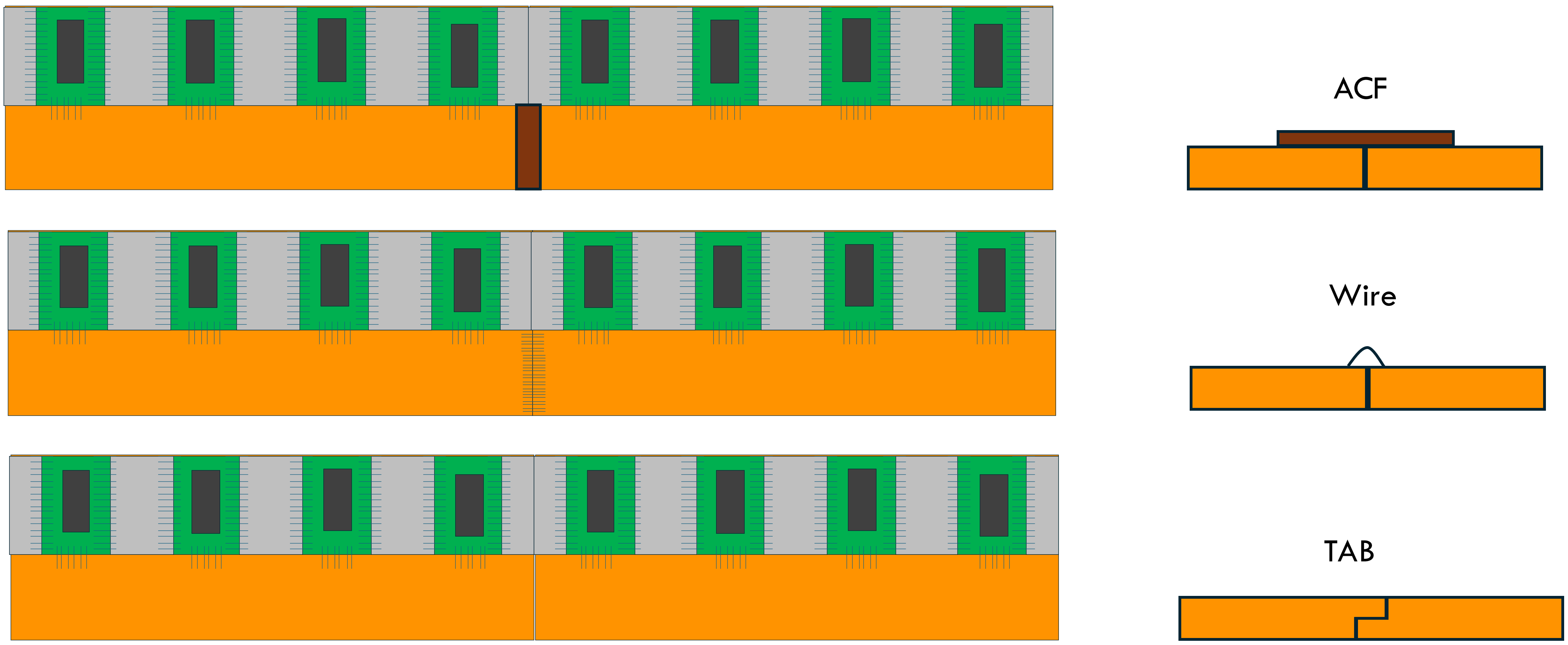
x 8 x 3 x 2 x 288
=13824



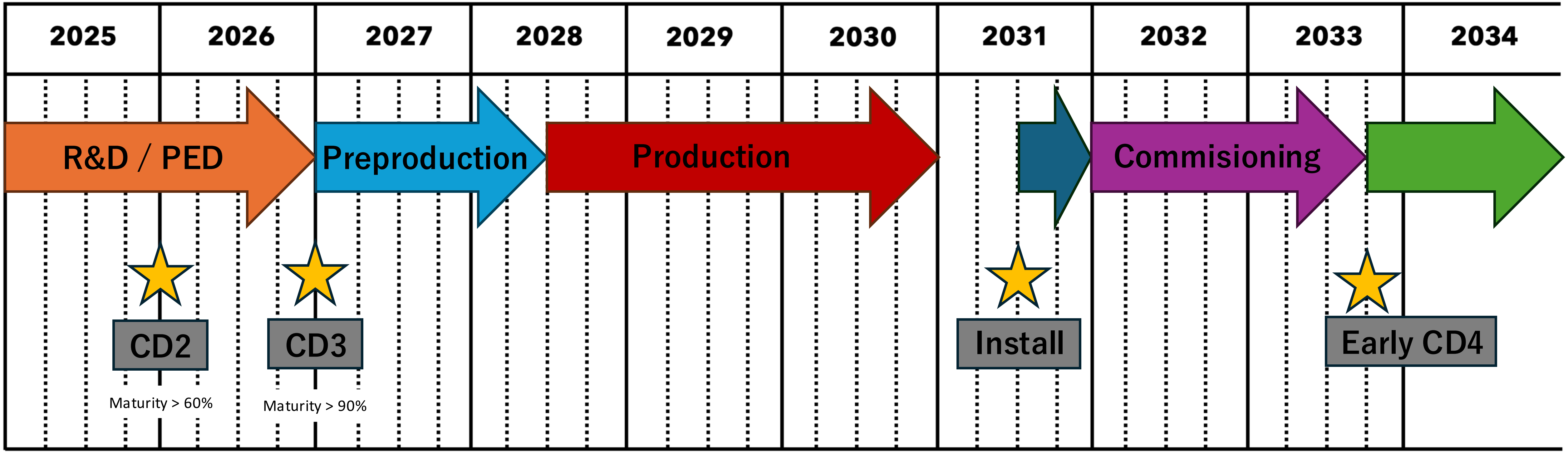
(2 x 8) x 2 x 288
=4608

- Envelop length for BTOF in z direction is ΔL = 2,675mm
- Current design is ΔL=2,816mm, so it must be 141mm shorten

Module Connection Method



ePIC Project Schedule (Best guess)



Sensor Performance

- **σ_{sensor}=35ps may not the best performance of strip-sensor**
  - Any readout boards used in tests were NOT tuned to strip sensor
    - C_d~10pF is expected but C_{input} = 4pF
  - However, even using best matching board, it is expected to not be significant improvement in 50um due to Landau Fluctuation

- **It is possible to improve timing resolution of thinner sensors**
  - Thinner sensor has small Landau fluctuation
  - Current worse resolution of 20um and 30um can be explained by smaller signal size due to using mismatching capacitance board
  - Thinner sensor capacitance C_d is proportional to 1/d and larger C_d makes worse rising time
  - Landau fluctuation v.s. C_d effect must be measured

Sensor R&D Strategy

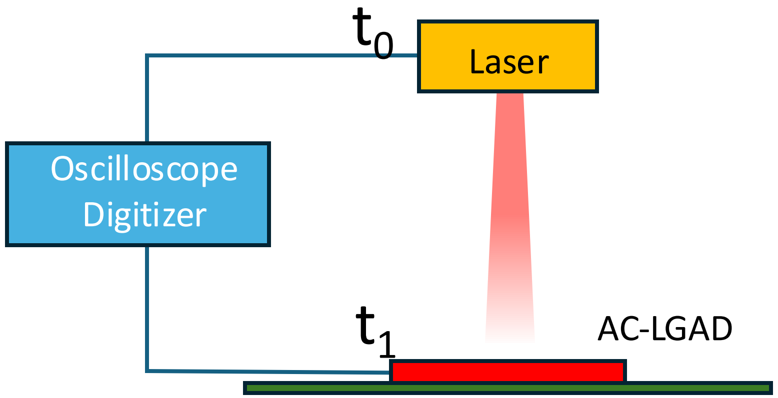
- It is impossible to improve sensor performance without adjusting readout board design
- The production cycle of ASIC is up to two times per year and need large funds, so it is better to use multiple simple readout boards and then reflect the result to ASIC design
- FCFDv1 result is the starting point to design the board
- LRC meter is one option to direct measurement of Cd, but 1GHz frequency is necessary to 100 ps rising time signal
    - Cd is varied by the frequency
    - Waiting for HPK answer if they will do it

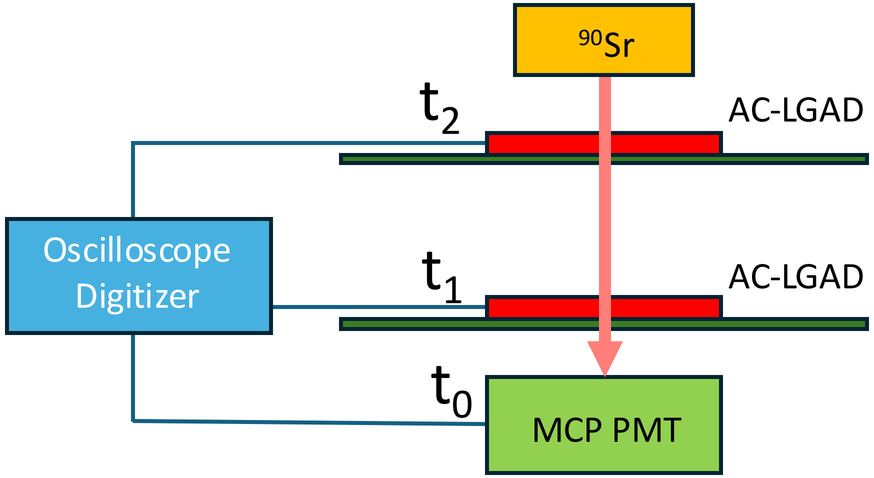
Sensor R&D Flowchart

1. **30um and 50um sensor test with FCFDv1 (C_{input}~10pF)**
   - We will see if the performance will be improved by the better capacitance matching
2. **Find/measure sensor capacitance C_d**
   - If possible LRC meter measurement
   - Fabricate the readout board based on FCFDv1 and/or LRC results
   - Clarify the potential of each sensor with lab test (^{90}Sr and IR laser)
   - Measure the real performance to MIP with test beam
3. **Feed back to the ASIC design**
   - Start the design with lab test result
   - Finalize assessment with test beam

Sensor Lab test

- Radiation source & IR Laser





- **TCT Scan (IR laser)**
  - Positioning resolution (charge sharing)
  - Signal properties w/ readout board
  - Better timing resolution than MIP
    - No Landau fluctuation

- **Performance evaluation w/ MIP**
  - Timing resolution of MIP
  - Path length form hit info of 2 sensors
  - Signal properties w/ readout board

IR Laser System

- **IR laser is used to measure signal properties**
  - Charge sharing between strips and rising time

- **UCSC recommends me to purchase the system from particulars (BNL uses the same system)**
  - Laser head, moving table (x-y-z), focusing optics, control software, and mechanical box

- **Pulse width >350 ps is worth resolution compared to sensor timing resolution, but it is not necessary to measure timing resolution**
  - Negotiable

- **"Large Scanning TCT" is preferred to purchase**
  - 10cm x 10cm x 10 cm (x-y-z), stage weight < 50kg

- **Following information was requested to the vender**
  1. Price (including any standard configurations and optional components)
  2. Estimated delivery time (lead time to Japan)
  3. Shipping cost to Japan
  4. Warranty and support details

Sensor + ASIC R&D Schedule

2025

Sample Sensor + UCSC board

Full size sensor property measurement
C_d, signal share and rise time

Sample Sensor + FDFDv1 (4ch)

FCFDv1 design assessment
C_{input} evaluation
Design Japanese board#1

Install IR Laser

Sample Sensor + Japan board#1

C_{input} design assessment
Feedback to FCFDv2 design
Design Japanese board#2

First test beam @ Japan

Japan Sensor#1 + Japan board#2

First "realistic" full size sensor properties measurement
C_d, signal share and rise time
Feedback to Japanese Sensor#2

6 months

2026

Wire bonding machine

Japan Sensor#1 + FCFDv2 (64ch)

FCFDv2 design assessment
C_{input} evaluation
Design Japanese board#3

6 months

Japan Sensor#2 + Japan board#3

Finalize C_{input} design
Finalize FCFDv3 design
Finalize Sensor design

Final Sensor + FCFDv3 (128ch)

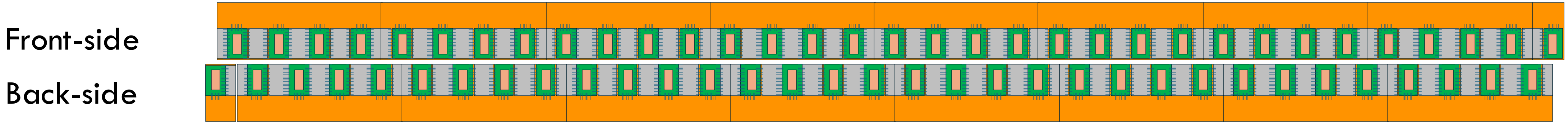
Converge designs

Stave Design Options

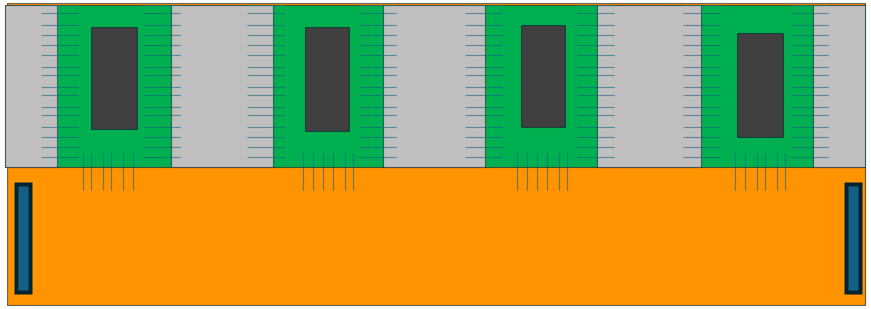
- **We have 2 scenarios:**
  - Opt1: Divide interposer into smaller pieces, but remain long FPC
    - Long FPC technology is required
  - Opt2: Divide interposer and FPC into smaller pieces
    - FPC connection technology is required

Stave Structure

Half-Stave = 1375.5 [mm] = 1344 [mm] + 31.5 [mm]

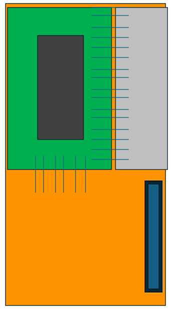


Module (Stavelet) = 168 [mm]

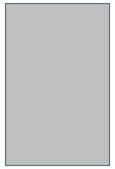


x 8 x 2 x 288
=4608

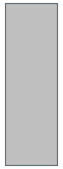
Mini-Module = 31.5 [mm]



x 1 x 2 x 288
=576

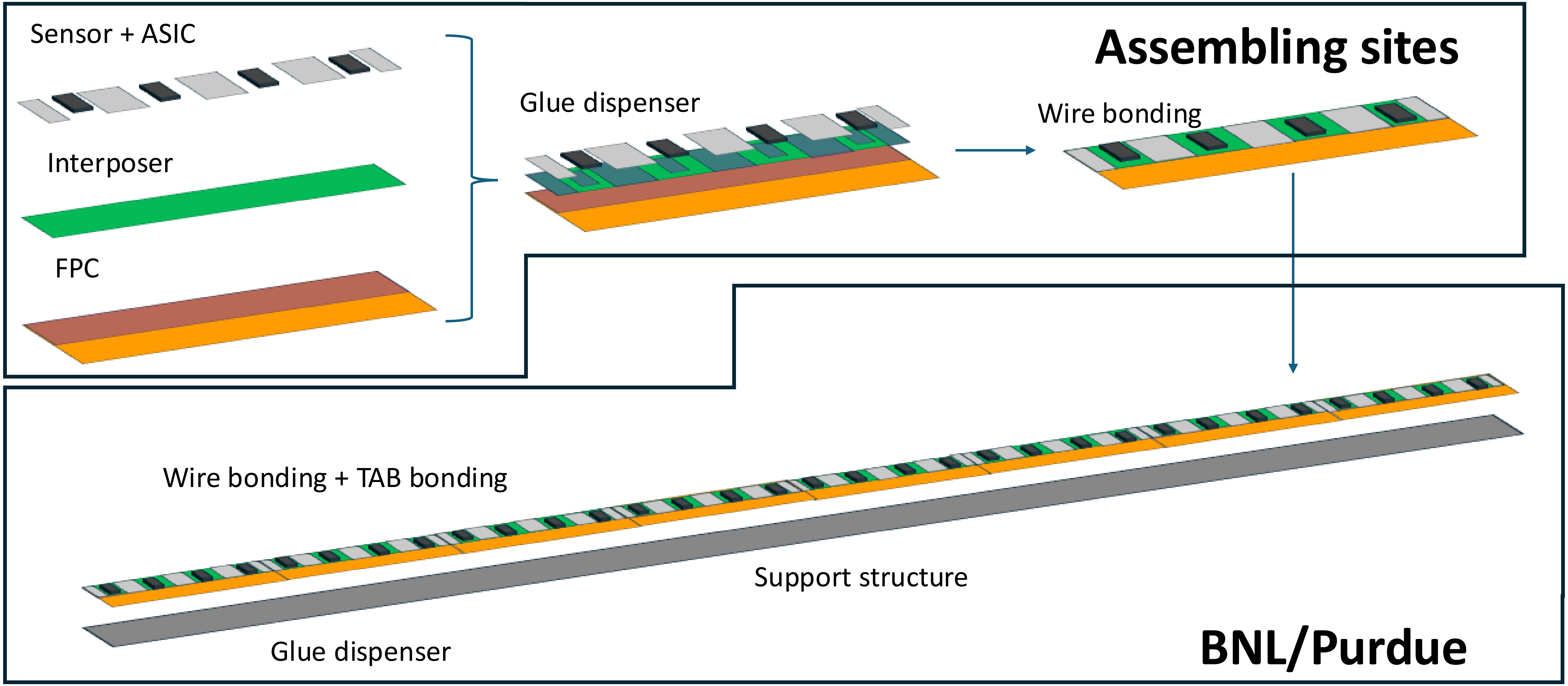


x 8 x 3 x 2 x 288
=13824

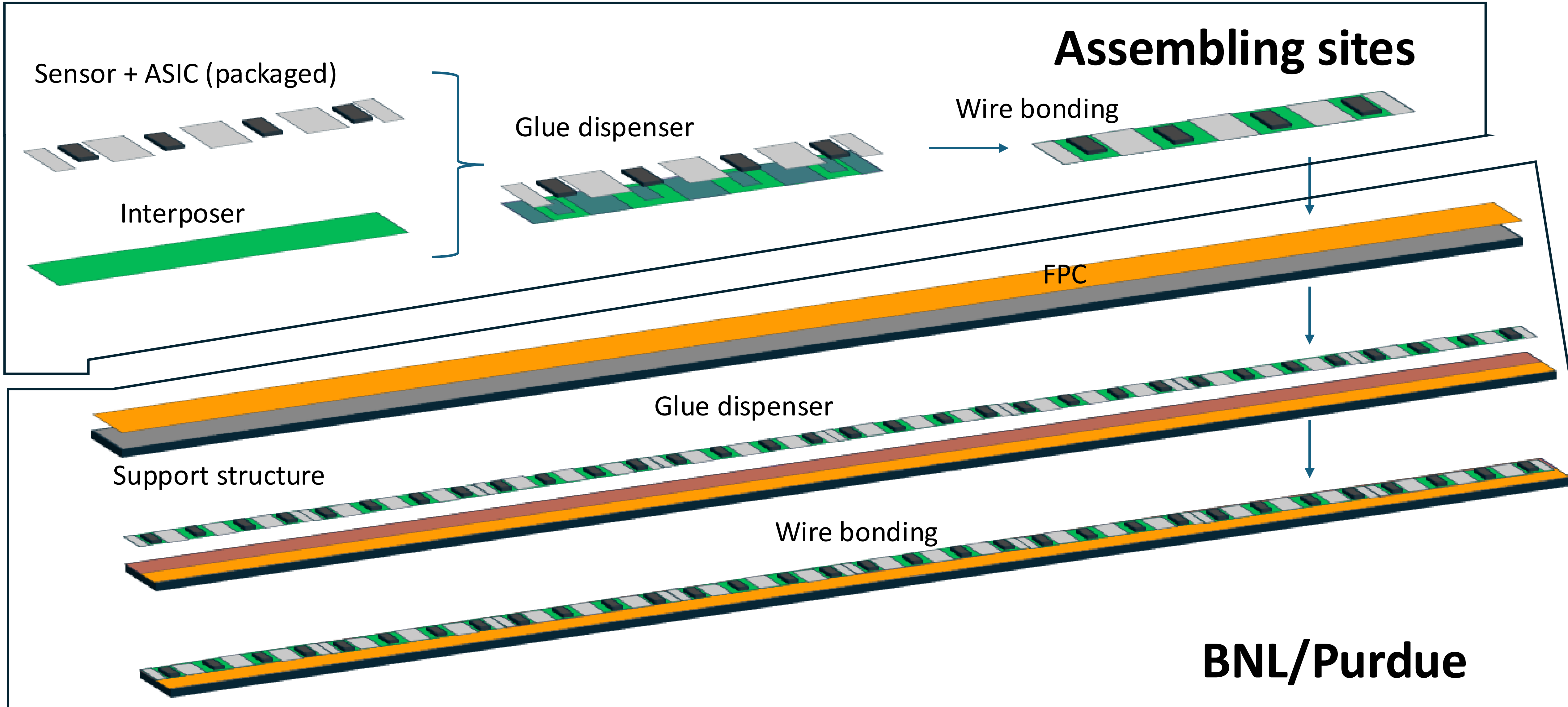


(2 x 8 + 2) x 2 x 288
=10368

Stave Assembling Process (Opt1)



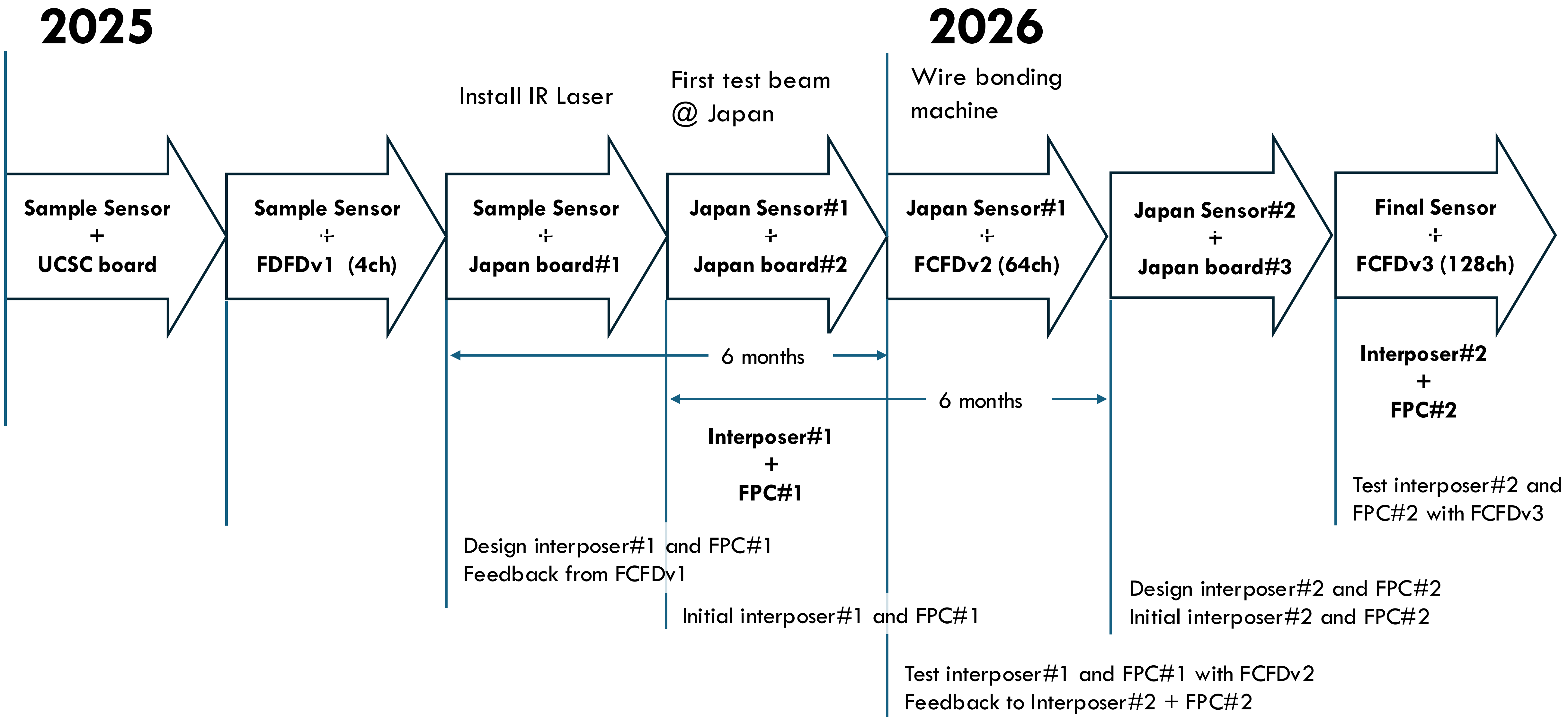
Stave Assembling Process (Opt2)



Assembling machines

- Opt1:
  - Machine can wire-bond 168mm module is required at each assembling site
  - Assembling space and bonding machine (wire or TAB bonding) for modules to half-stave (1375.5mm) is necessary at BNL
- Opt2:
  - Machine can wire-bond 1375.5mm half-stave is required at each assembling site
  - Assembling space and bonding machine (wire) for modules to half-stave (1375.5mm) is necessary at BNL
- Option1&2:
  - Automatic glue dispenser?

R&D Schedule



2025
2026
Install IR Laser
First test beam @ Japan
Wire bonding machine
Sample Sensor + UCSC board
Sample Sensor + FDFDv1 (4ch)
Sample Sensor + Japan board#1
Japan Sensor#1 + Japan board#2
Japan Sensor#1 + FCFDv2 (64ch)
Japan Sensor#2 + Japan board#3
Final Sensor + FCFDv3 (128ch)
6 months
6 months
Interposer#1 + FPC#1
Interposer#2 + FPC#2
Test interposer#2 and FPC#2 with FCFDv3
Design interposer#1 and FPC#1
Feedback from FCFDv1
Initial interposer#1 and FPC#1
Design interposer#2 and FPC#2
Initial interposer#2 and FPC#2
Test interposer#1 and FPC#1 with FCFDv2
Feedback to Interposer#2 + FPC#2