Minimum Timing Resolution Needed

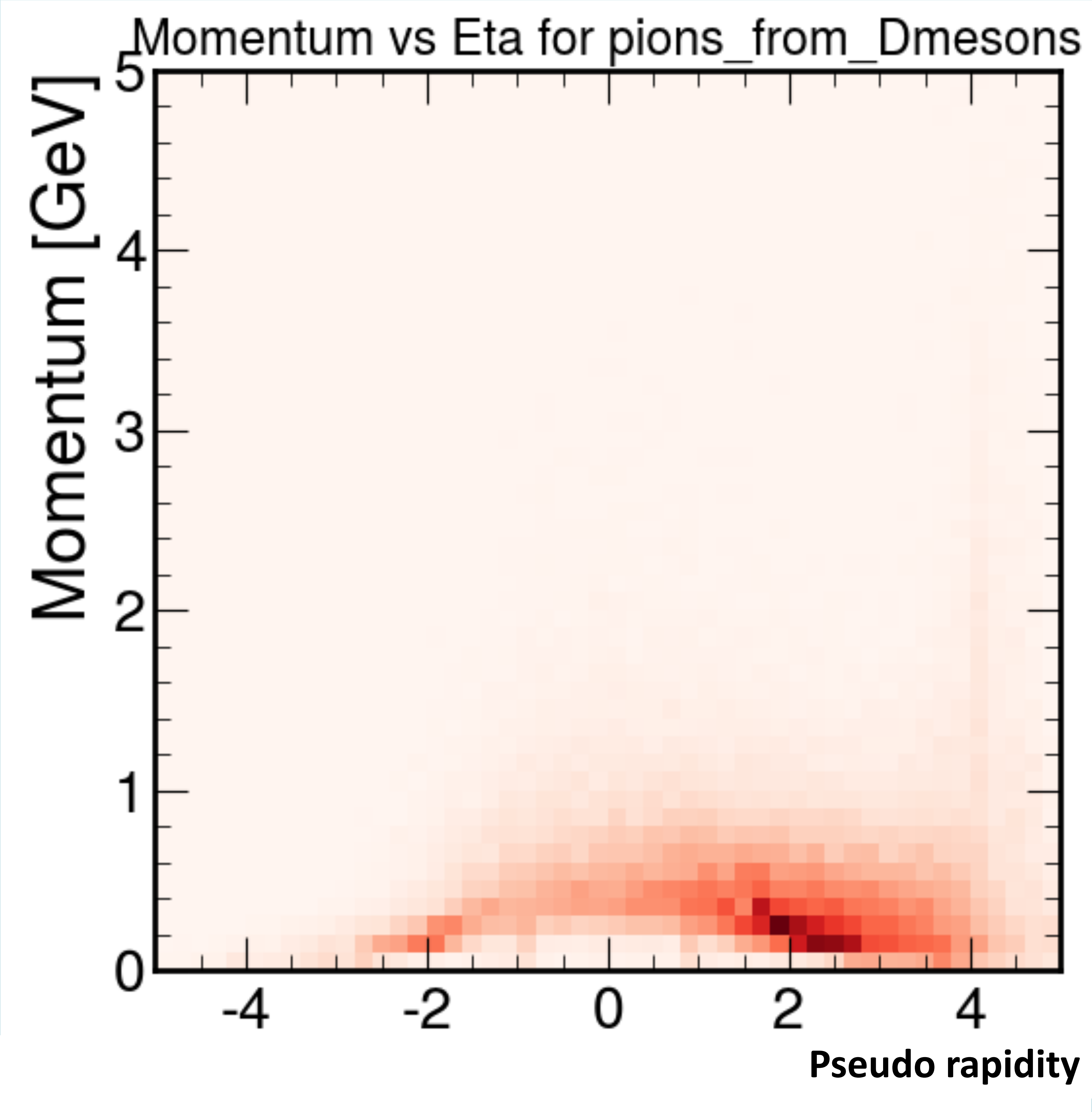
Satoshi Yano (Hiroshima University)

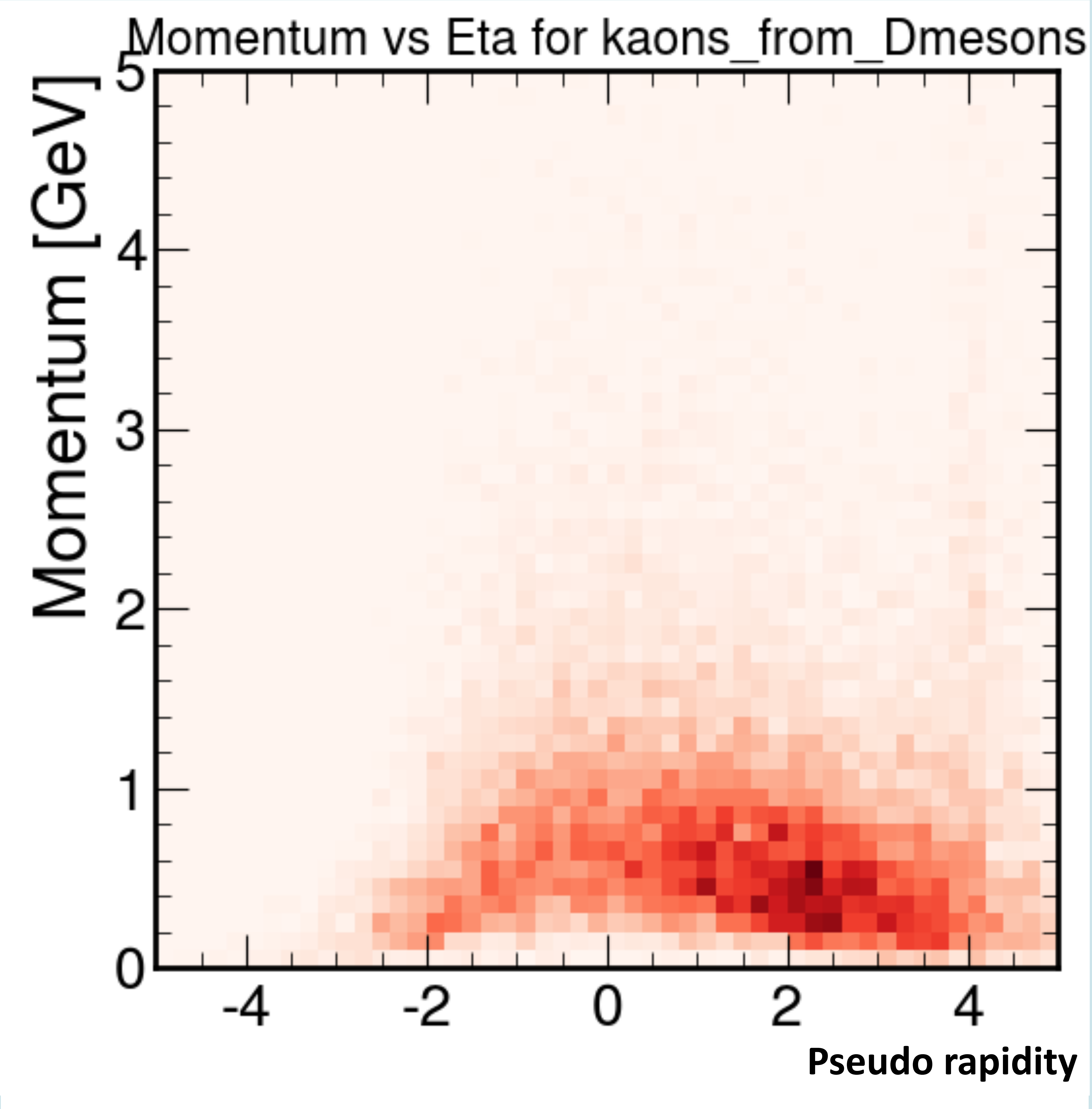
Required PID Performance in pre-TDR

Achieving the PID goals of the ePIC experiment requires multiple detection technologies tailored to specific momentum and pseudorapidity ranges. Cherenkov radiation detection is the primary method at higher momenta but is limited in its low-momentum reach. After the Yellow Report, it was realized that improving low-momentum PID is critical for light vector meson and charm meson/baryon reconstruction. To address this, Time-of-Flight (ToF) detectors based on finely pixelated AC-LGAD sensors were added in the barrel (0.5×10 mm pixels) and forward region (0.5×0.5 mm pixels). In addition to PID they will additional hits for tracking. The η-dependence of the momentum spectrum along with space constraints necessitate different technologies in the forward, backward, and barrel regions. The solution chosen by ePIC involves:

Decay product kinematics from D-meson

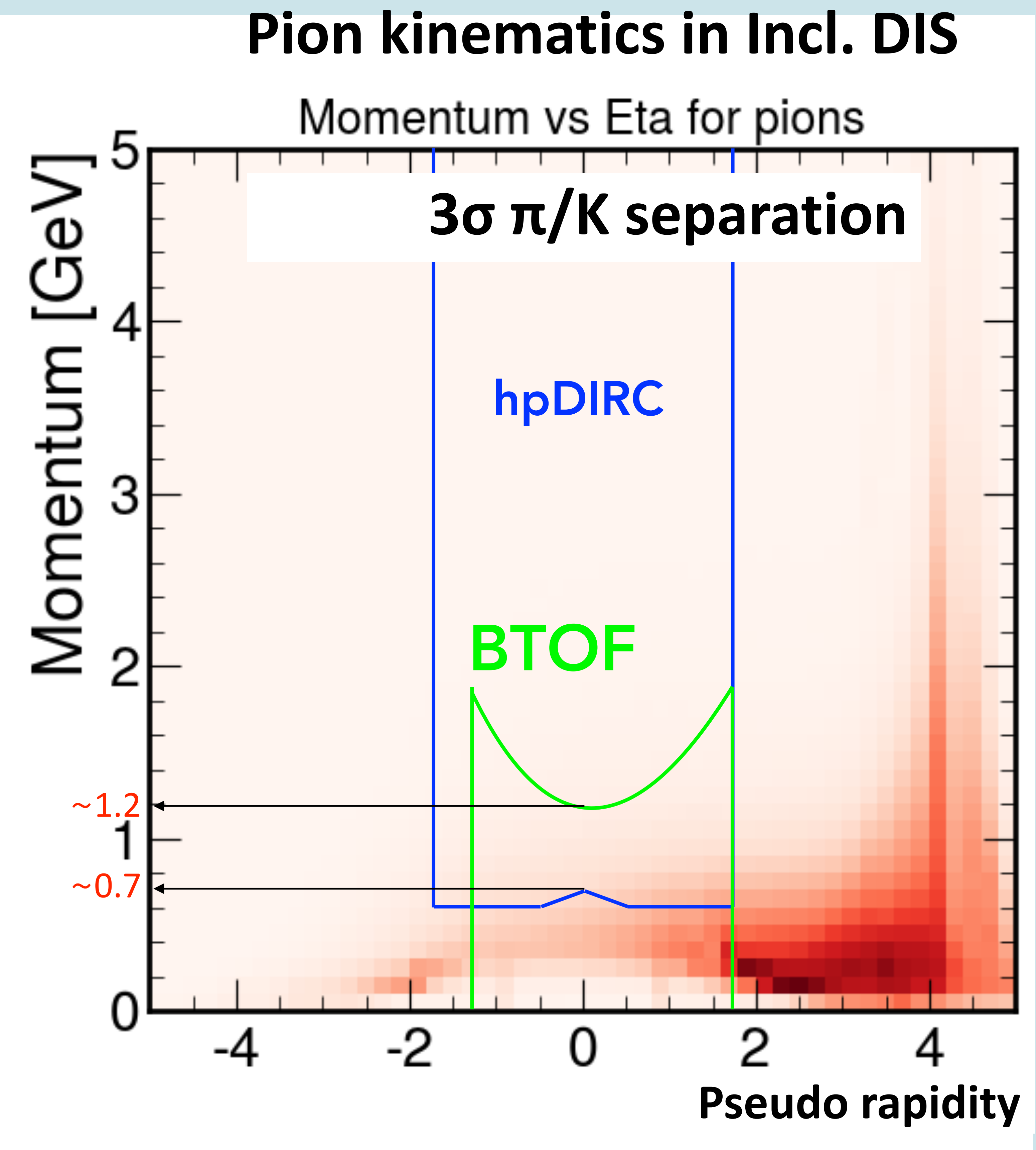
These plots are provided by Kentaro

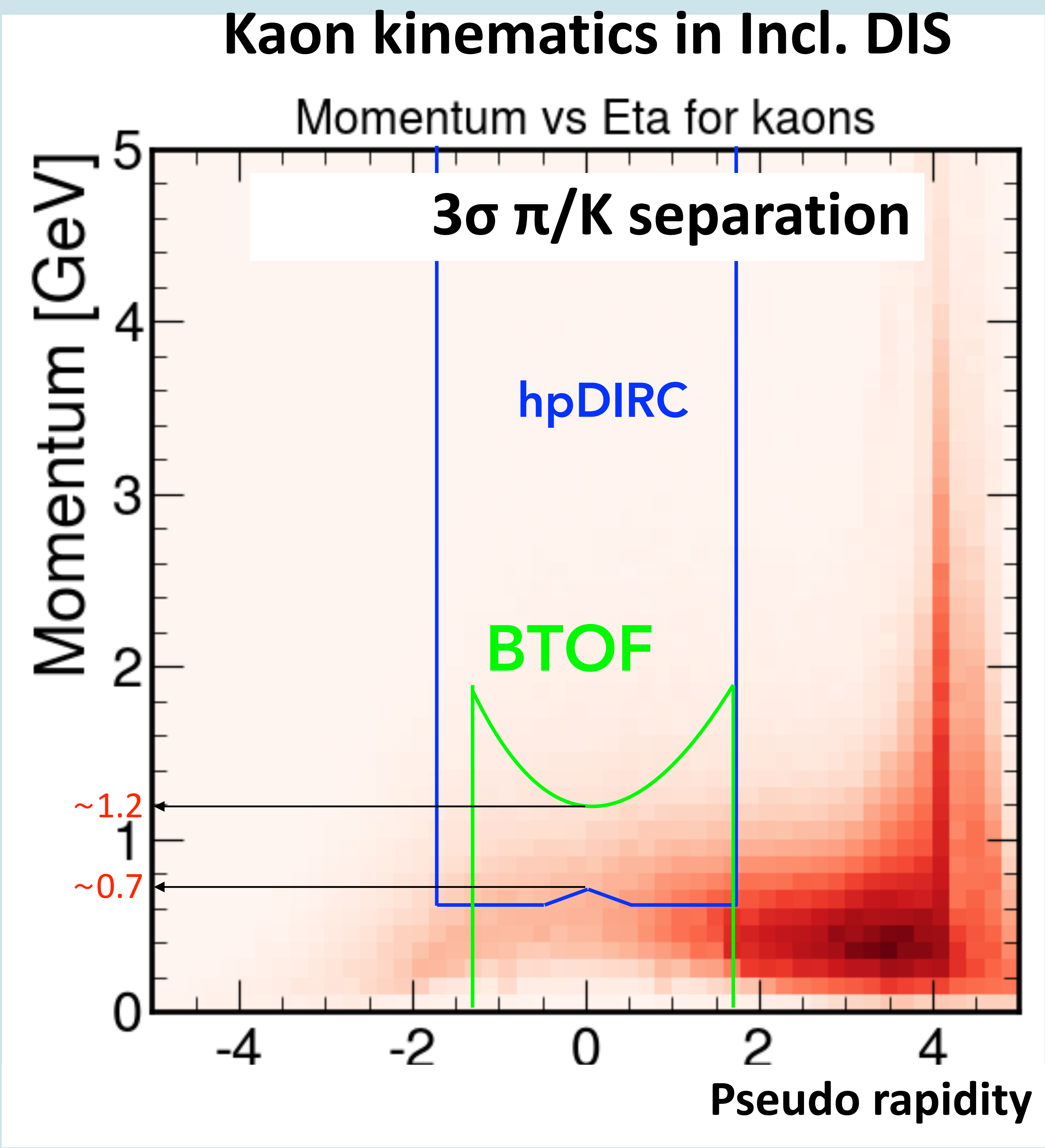


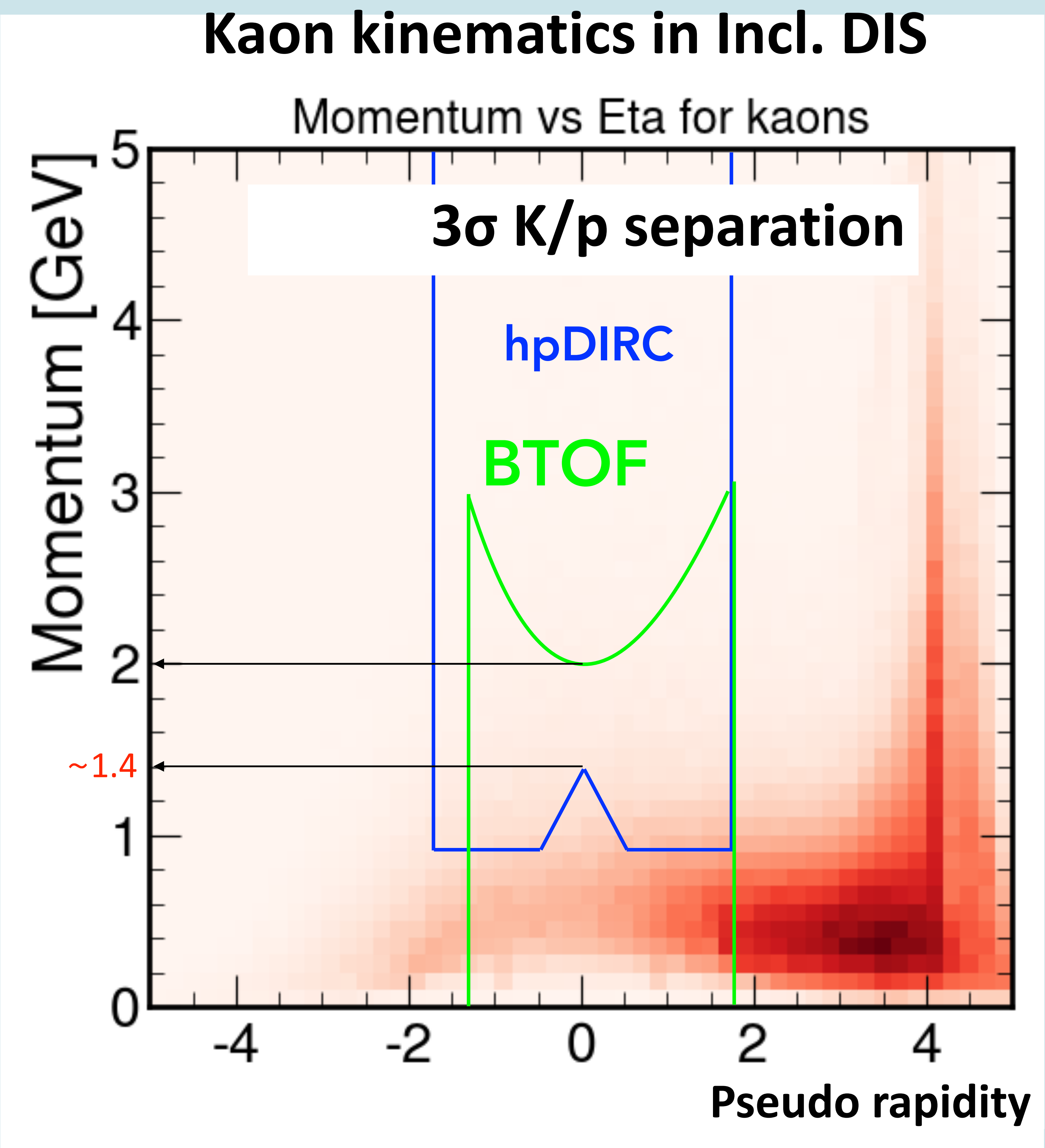


PID performance with 35 ps timing resolution

These plots are provided by Kentaro





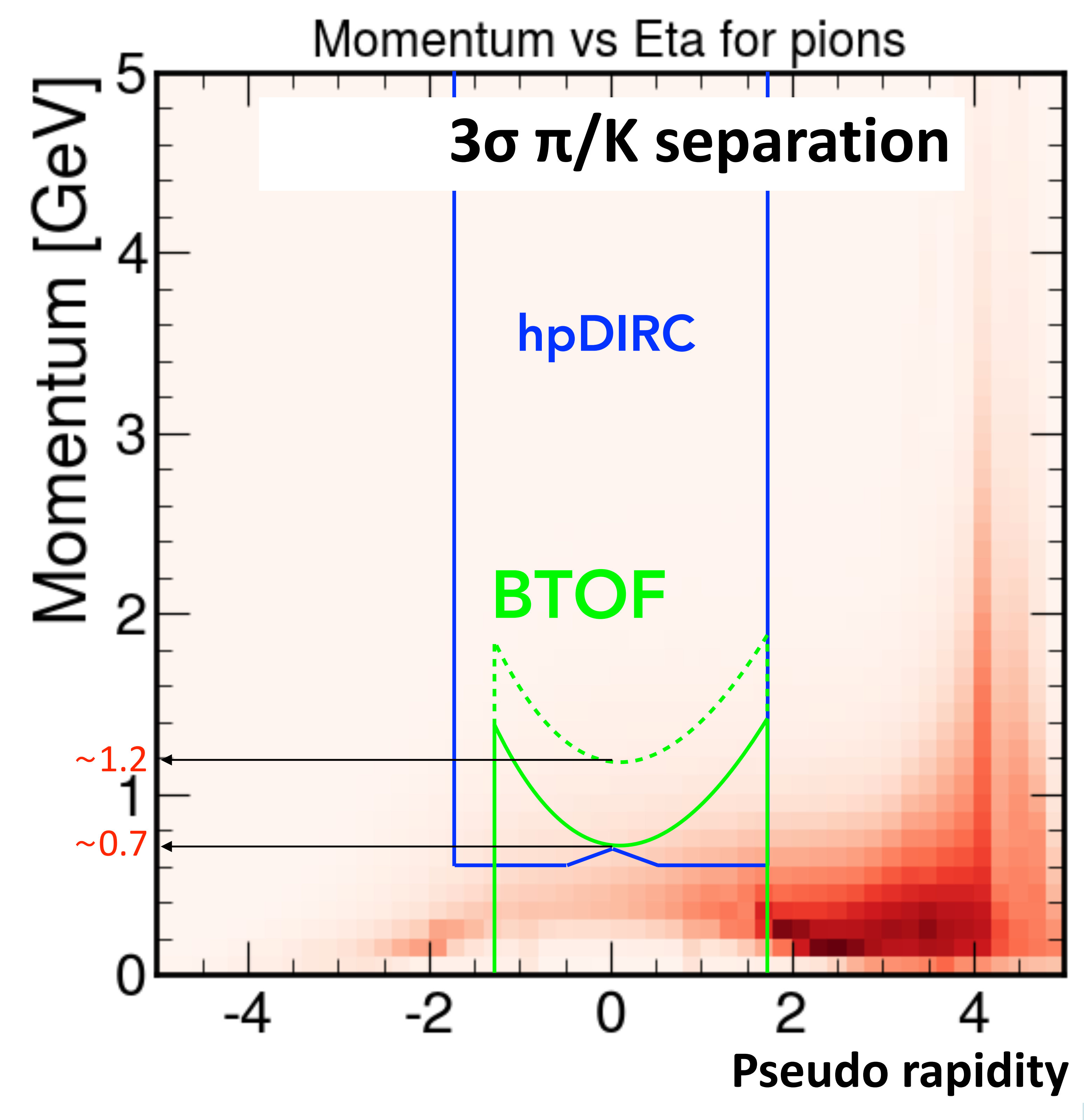


- BTOF with 35ps timing resolution area is shown in Green (hpDIRC is blue)
- At center of the acceptance, BTOF can separate up to ~1.3 GeV/c π/K separation and ~2GeV/c K/p separation
- At center of the acceptance, hpDIRC can separate down to ~0.7 GeV/c π/K separation and ~1.4 GeV/c K/p separation

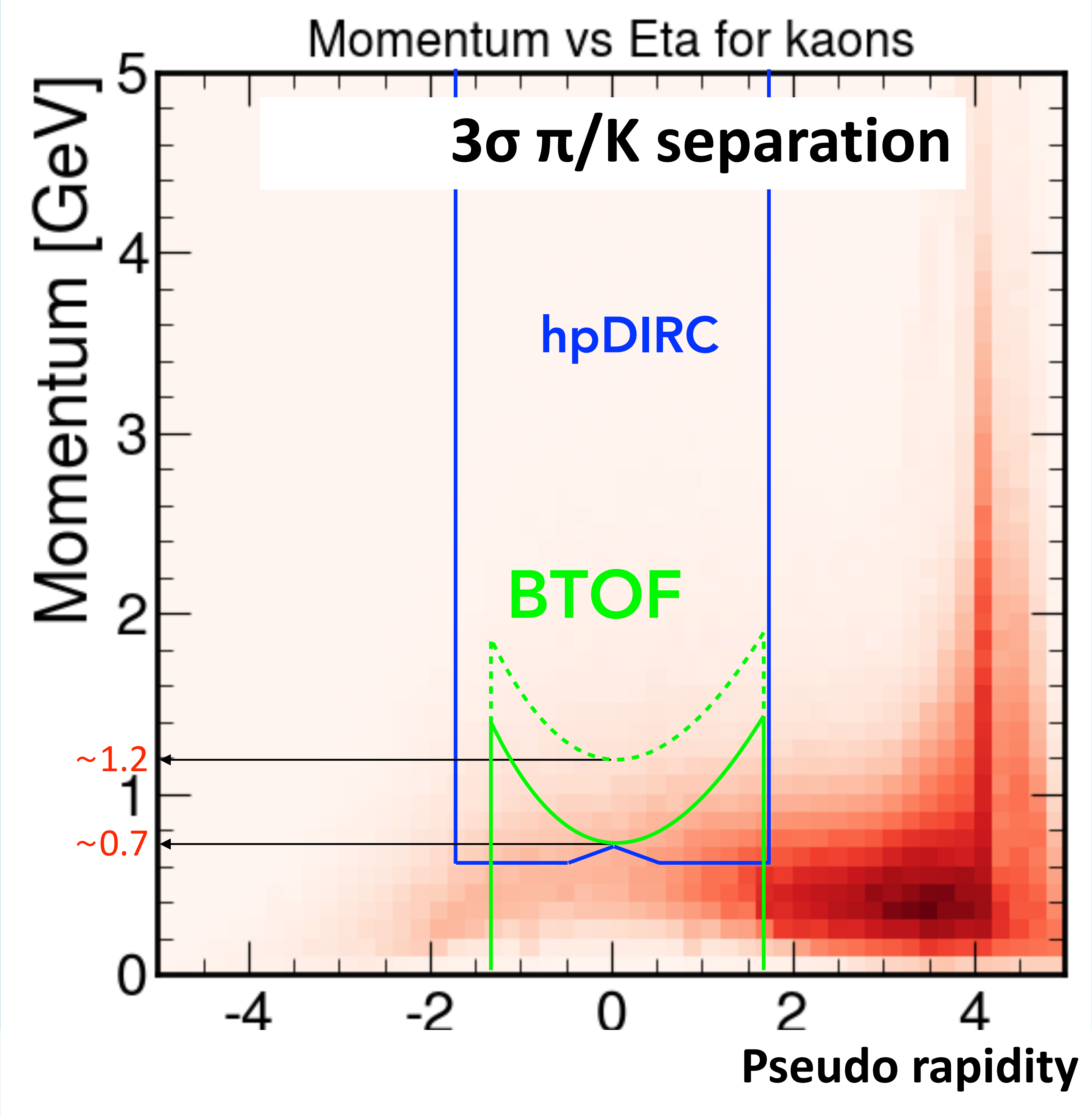
Loosest PID Requirements

These plots are provided by Kentaro

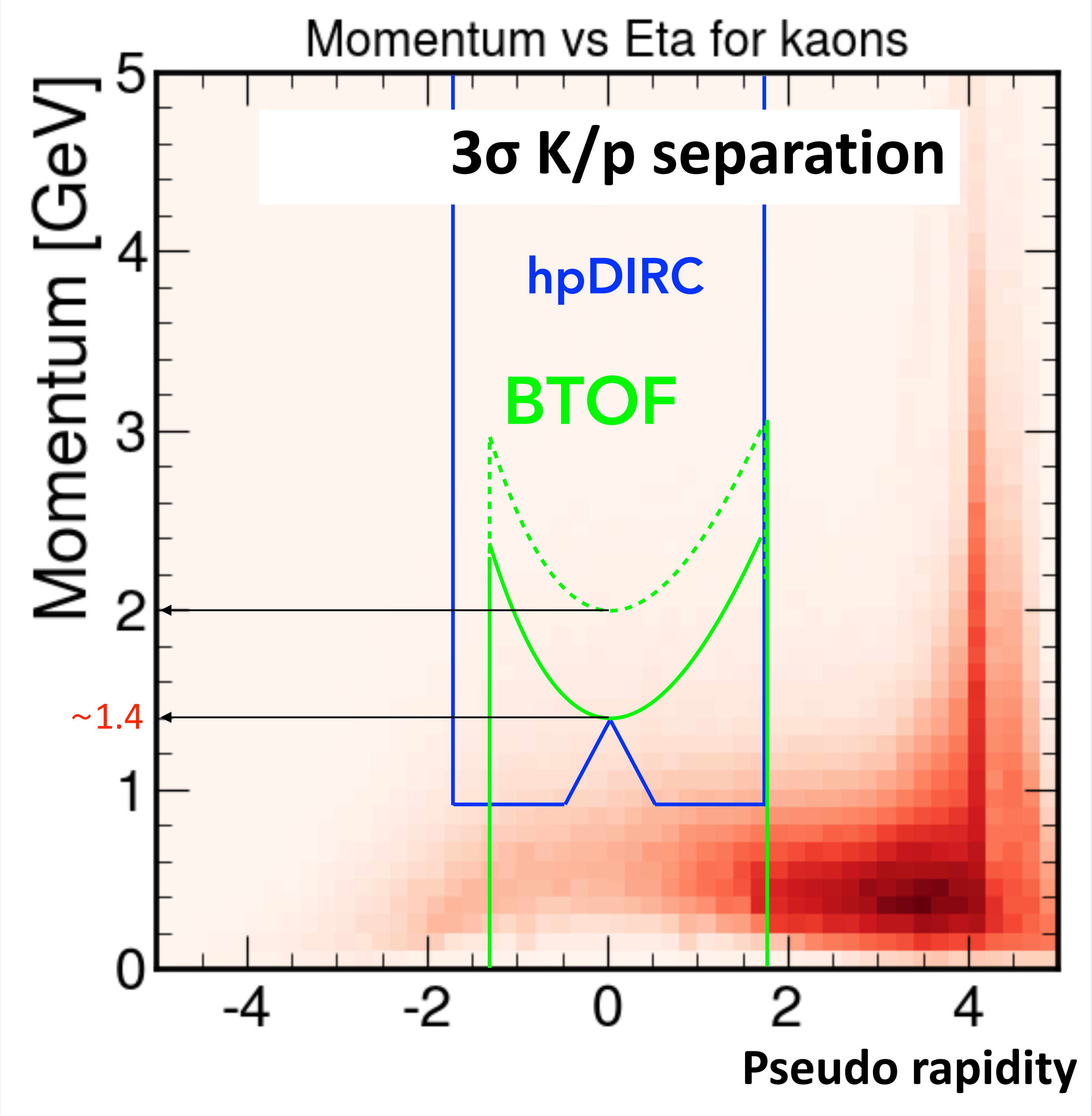
Pion kinematics in Incl. DIS



Kaon kinematics in Incl. DIS



Kaon kinematics in Incl. DIS



- The minimum time resolution required is the case that matches the maximum momentum limit of BTOF and the minimum momentum limit of hpDIRC
- The value from π/K separation up to 0.7 GeV is ~60 ps and from K/p separation up 1.4 GeV/c is **~50 ps**

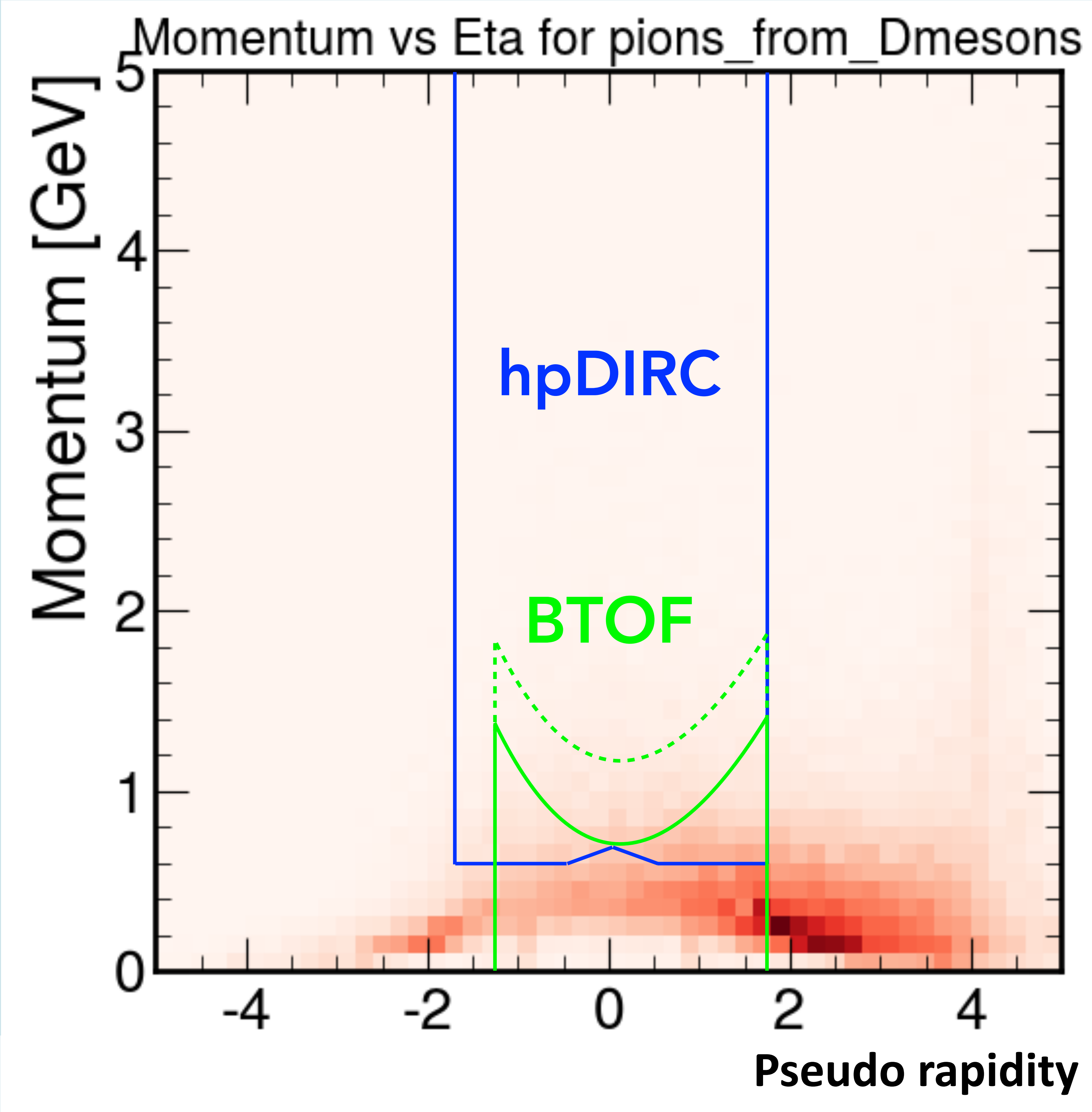
Minimum timing resolution of sensor

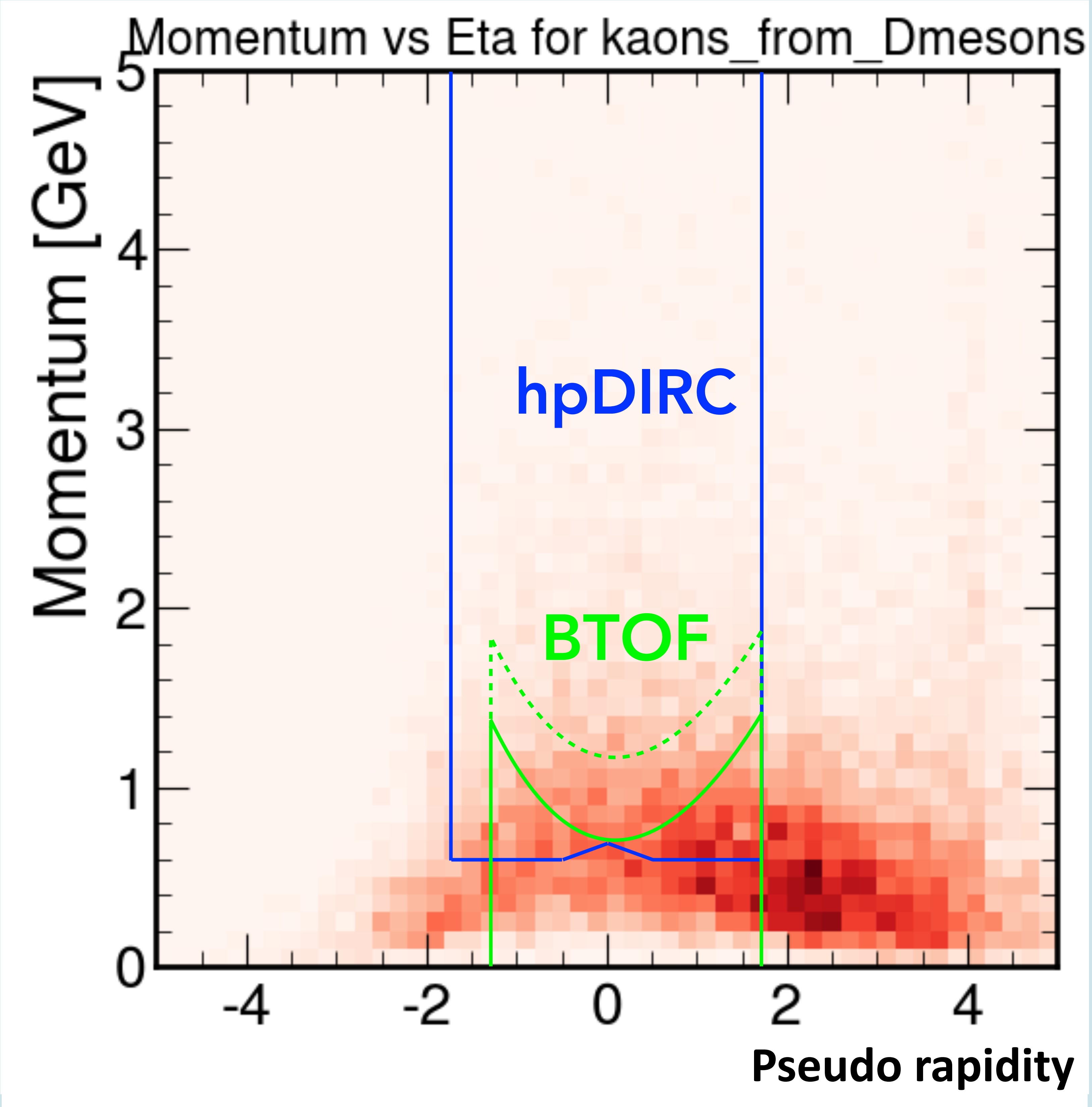
- The best timing resolution is σ_{sensor} ~35 ps for strip sensor
  - Timing resolution of "BTOF" is σ_{BTOF} ~ 43 ps (σ_{ASIC} = 20 ps, and σ_{T0} = 15 ps are assumed)

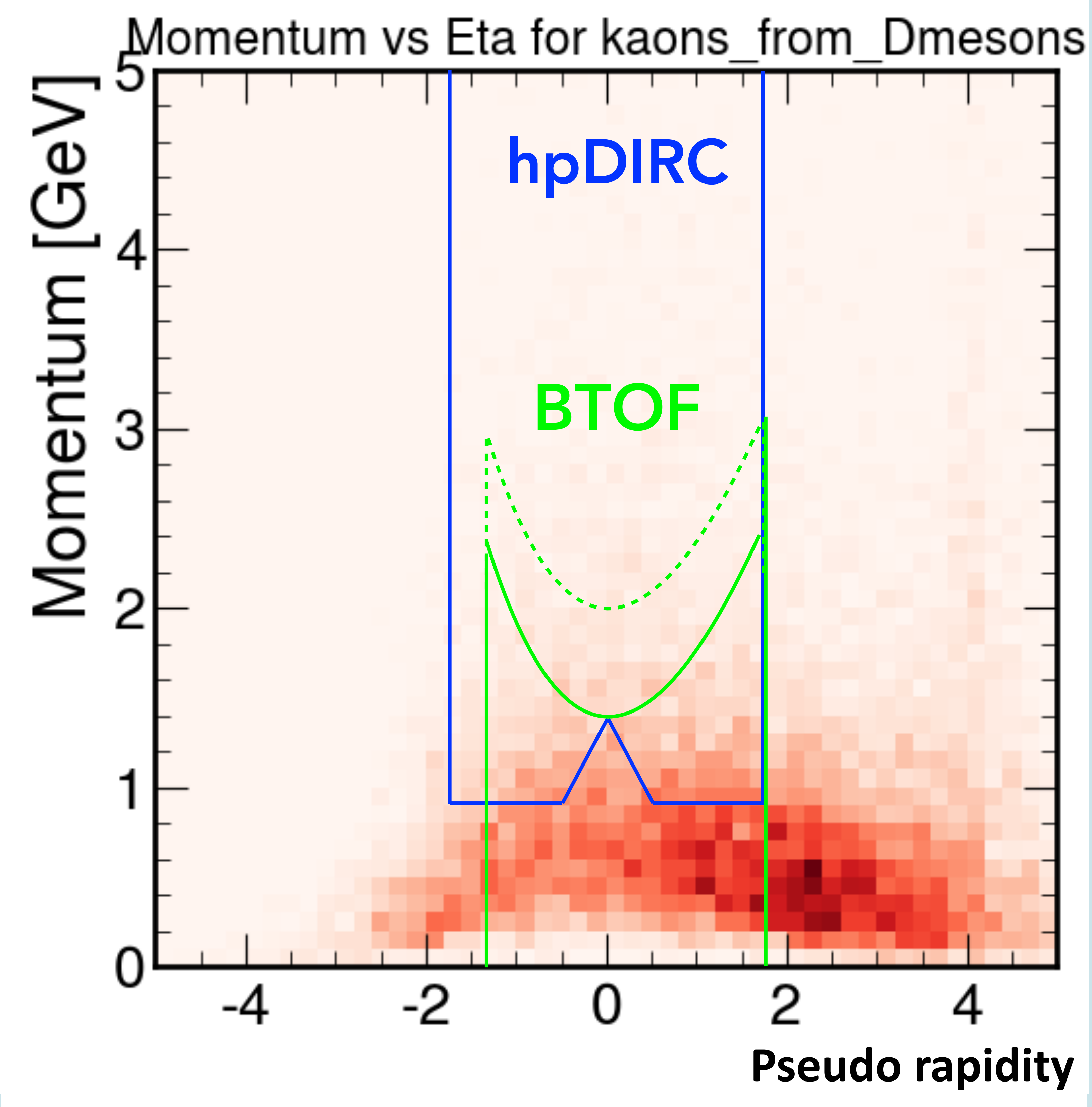
- The minimum time resolution of sensor allowed is **$\boldsymbol{\sigma_{sensor}}$ ~ 43 ps**
  - σ_{BTOF} ~ 50 ps when σ_{ASIC} = 20 ps, and σ_{T0} = 15 ps

Decay product kinematics from D-meson

These plots are provided by Kentaro







Backup

m=month

EIC Critical Decision Plan (Old)	
CD-0/Site Selection	December 2019
CD-1	June 2021
CD-3A	Jan 2024
CD-3B	Jan 2025
CD-2	Jan 2025
CD-3	Apr 2025
Early CD-4	Apr 2032
CD-4	Apr 2034

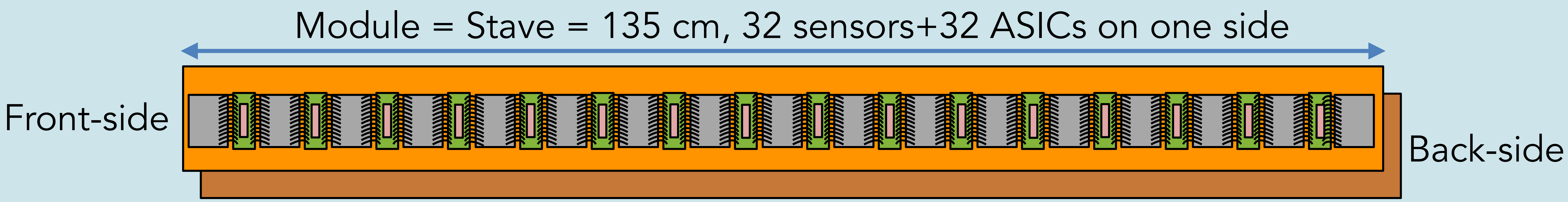
EIC Critical Decision Plan (Latest)	
CD-0/Site Selection	**December 2019**
CD-1	**June 2021**
CD-3A	**March 2024**
CD-3B	**January 2025**
CD-2/3C	Q2 FY26
CD-3	Q2 FY27
Early CD-4	Q1 FY34
CD-4	Q4 FY35

Stave design baseline

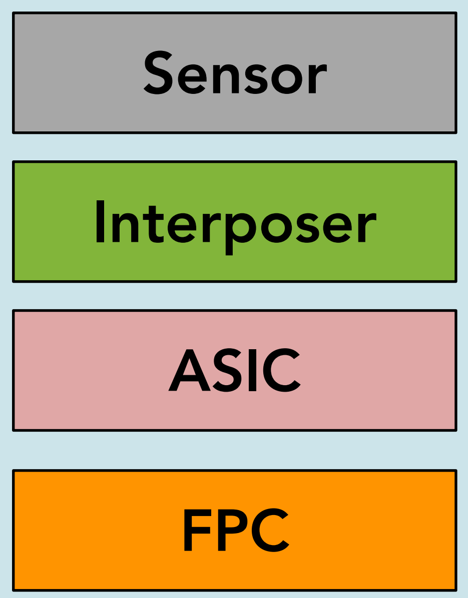
- The stave length is 270cm (2 x 135cm half-staves)
  - Attached 32 sensors and 32 ASICs on each side (front and back) of one half-stave
  - No modularization is considered (one-shot deal)

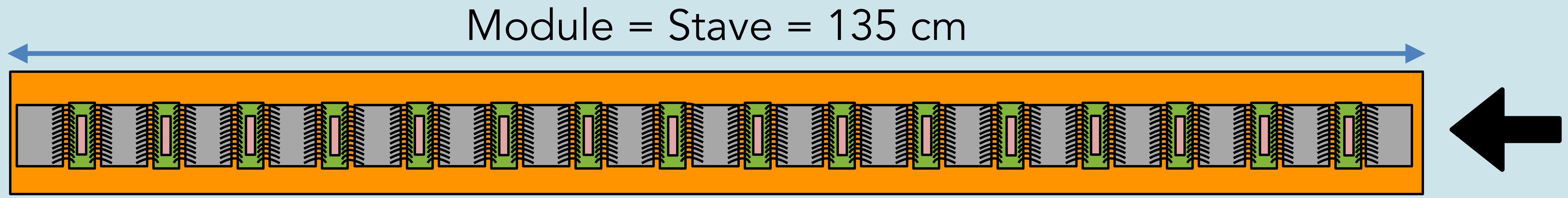
- While this design has the advantage of low-material budget, the assembling difficulties remain concerned
  - 135 cm long with low material = it is difficult to control deflection
  - Gluing sensors & ASICs with 135 cm long with low material = it is difficult to care of back side component

- **Special care (modulization) is neccesary to assemble such a large (long) and low material detector**

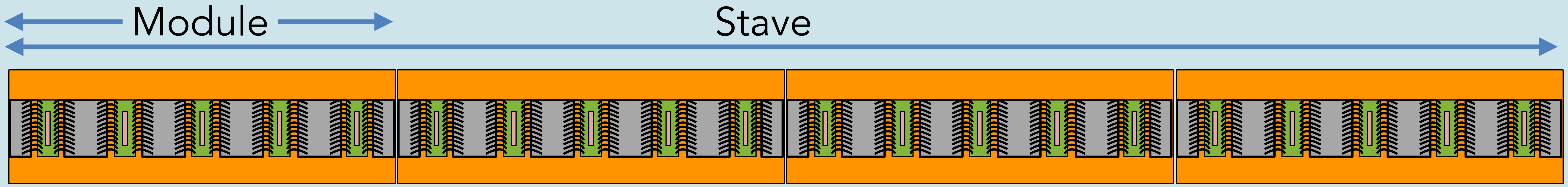


Stave design ideas

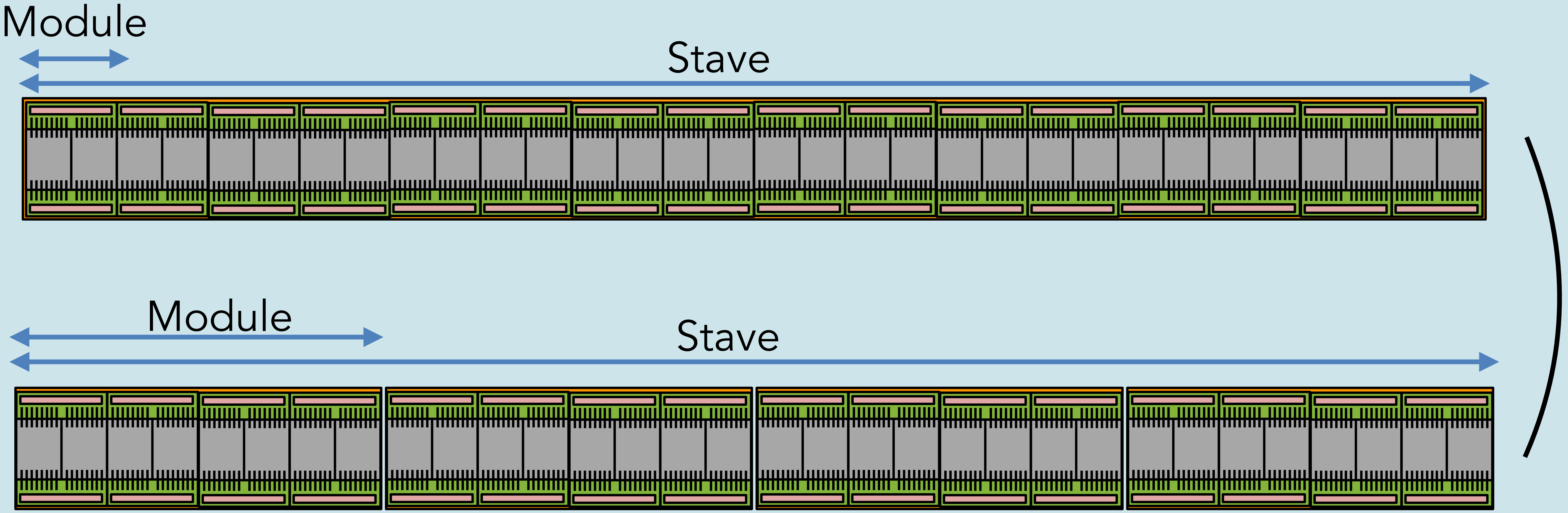




Baseline Design 128 sensors 128 ASICs



Need Tab bonding



Need double metal layer


Mechanical Production
Mechanical QA
Sensor Production
Sensor QA
ASIC Production
ASIC Package
ASIC QA
Interposer Production
Interposer QA
FPC Production
FPC QA
Electronics Purchase
RB Assembling
PB Assembling
RB QA
PB QA
SH Assembling
SH QA
Module assembling
Module QA
Stave assembling
Stave QA
BTOF construction
BTOF QA
Install to ePIC
Commisioning
WP1: Sensor
WP2: Frontend Electronics
WP3: Module Integration and Assembly
WP4: System Tests and Validation
WP5: Mechanical Structure
WP6: DAQ and Clock
WP7: DCS
WP8: Simulation, Software & Calibration

In the near future...

Sensor QA/QC

Sensor Production
BNL/HPK/TSMC

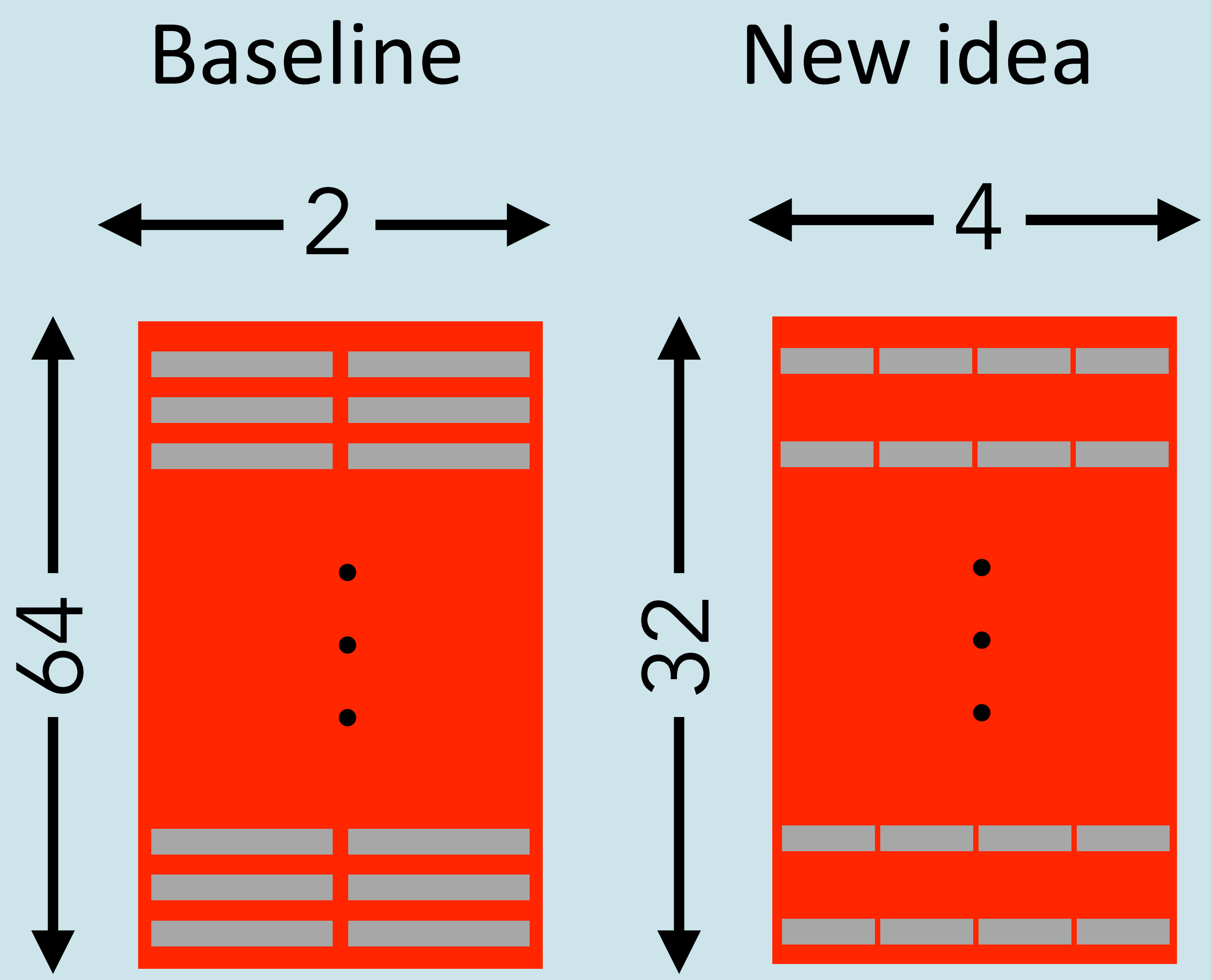
- **Quality Contorol**
  - Visual inspection
  - IV measurement
  - Metrology
- **Quality Assuarance**
  - IR laser test
  - Irradiation
    - IR laser test

Task	Subtask	Institute	Person
Sensor	R&D		
	QA		
ASIC	R&D		
	Packaging		
	QA		
Interposer	R&D		
	QA		
FPC	R&D		
	QA		
PB	R&D		
	Assembling		
	QA		
RB	R&D		
	Assembling		
	QA		
SH	R&D		
	Assembling		
	QA		
Mechanical	R&D		
	QA		
Module	R&D		
	Assembling		
	QA		
Stave	R&D		
	Assembling		
	QA		

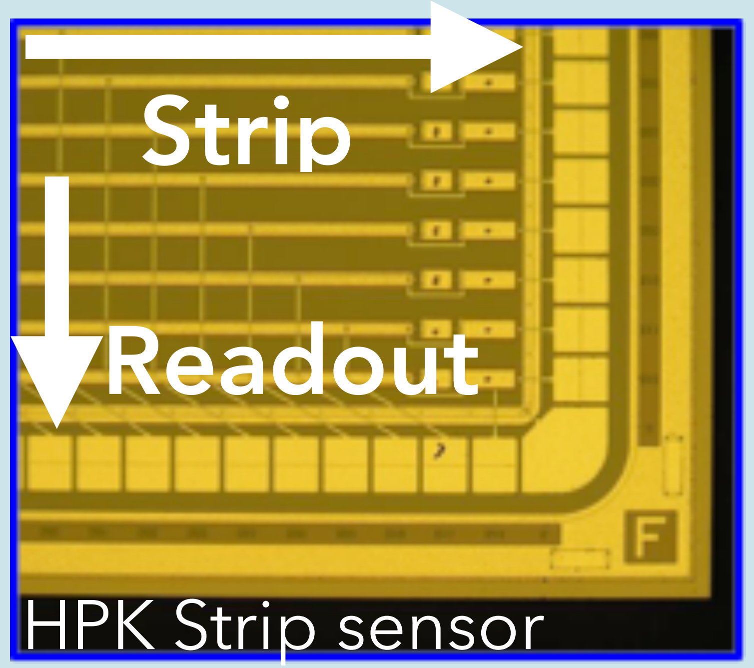
- In the near future, we would like to determine in more detail what each task entails and who will be responsible for and work on each task
- The left table is the starting point. Let's build each task in detail by the dedicated WP
- By creating this table, it becomes clear what is being done, where, and by whom, so that future personnel and budget allocations can be determined efficiently and without waste

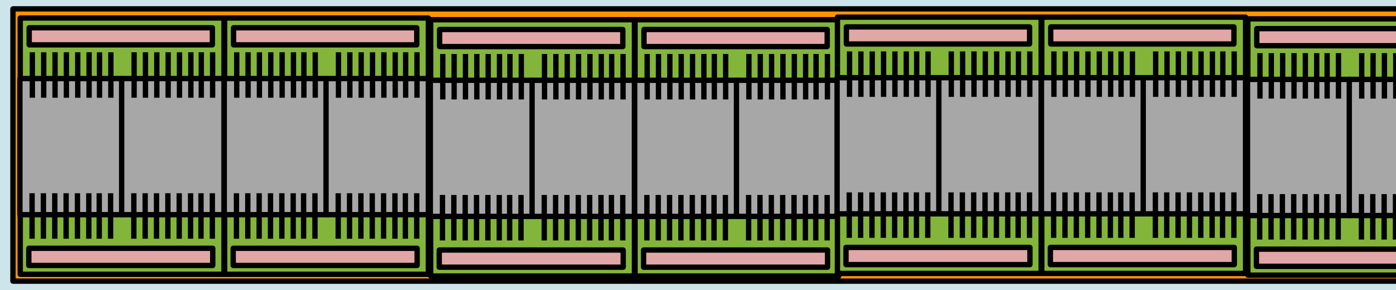
Roadmap (ver0)

Fabricate HPK sensors



- We are preparing for the stipe sensor production
- "Baseline" sensors
  - 64x2 = 128 ch, 10x0.5 mm^2 readout pads, 30/50μm thickness
- Higher performance sensors
  - New geometry to achieve better timing resolution with reasonable posisioning resolution
  - Shorter strip metal but wider pitch
- Double metal layer sensor
  - Easy assembly and mechanical structure
  - Single-side readout and double-side readout



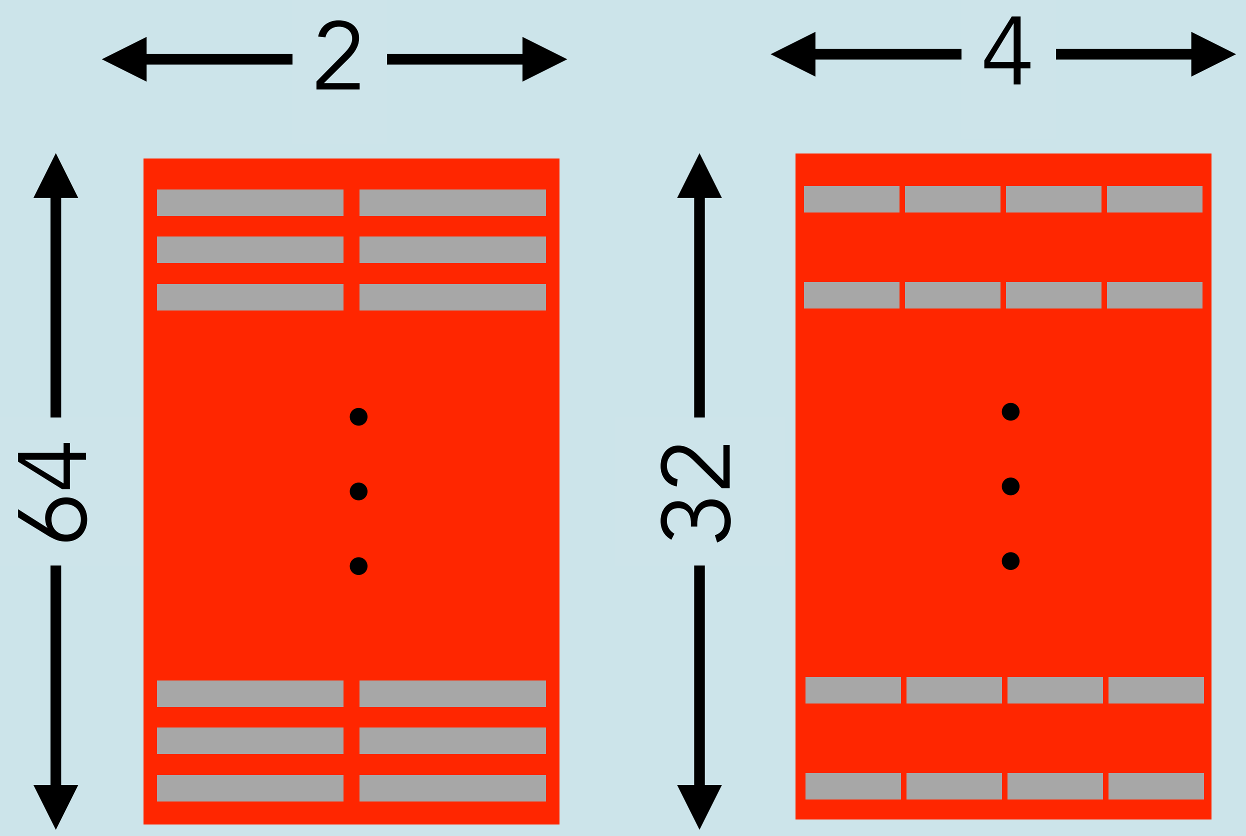


Anything else?

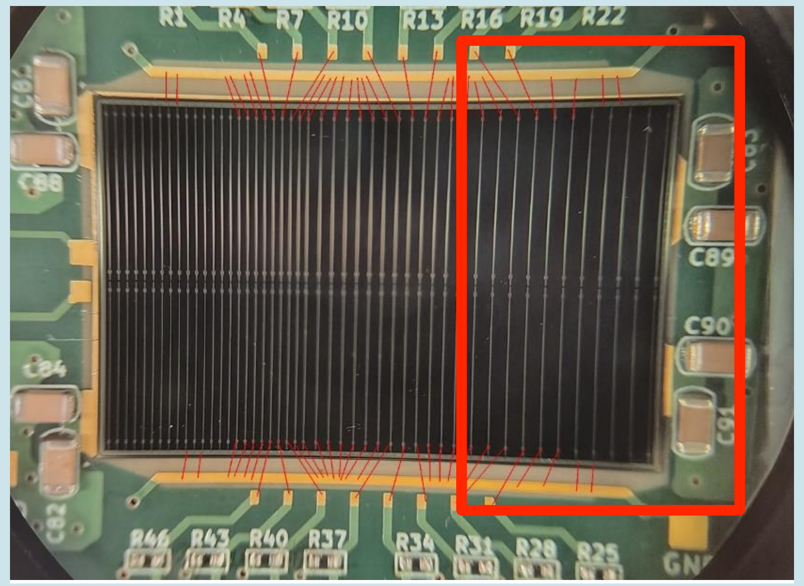
ピッチを長く、電極長を短く

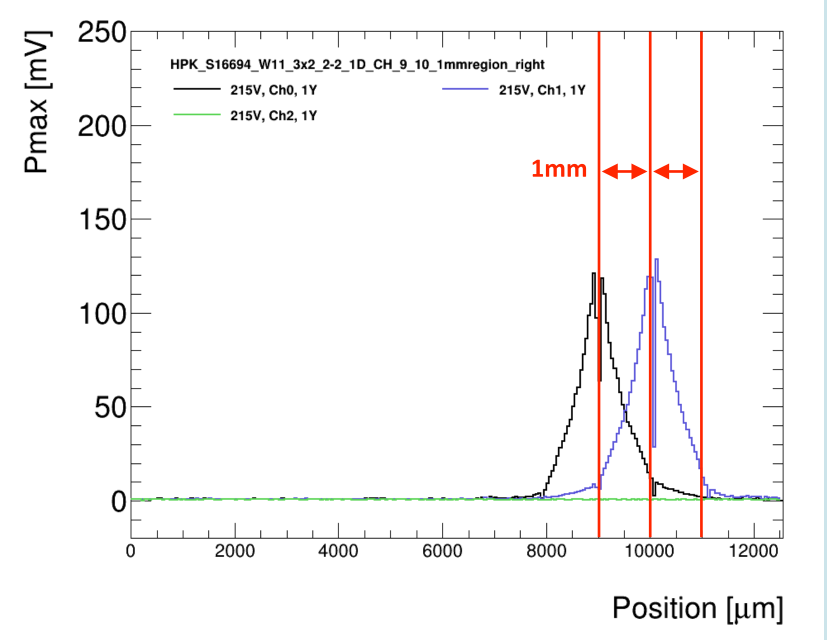
- 10 x 0.05 mm²サイズ、0.5mmピッチの読み出し電極を5 x 0.05 mm²サイズ、1 mmピッチに変更
  - 電極長の縮小により寄生容量の減少
  - ピッチ長の変更による位置分解能の性能は劣化
  - 全体のチャンネル数は変更なし（2x64=128 → 4x32=128）
  - **4列になるためダブルメタルレイヤー（次ページ）の実装が必須**
  - 他の電極も試す価値あり？

- 寄生容量を小さくしたことで薄いセンサーにおいても信号が大きくなる
  - さまざまな厚さのセンサーを試作したい

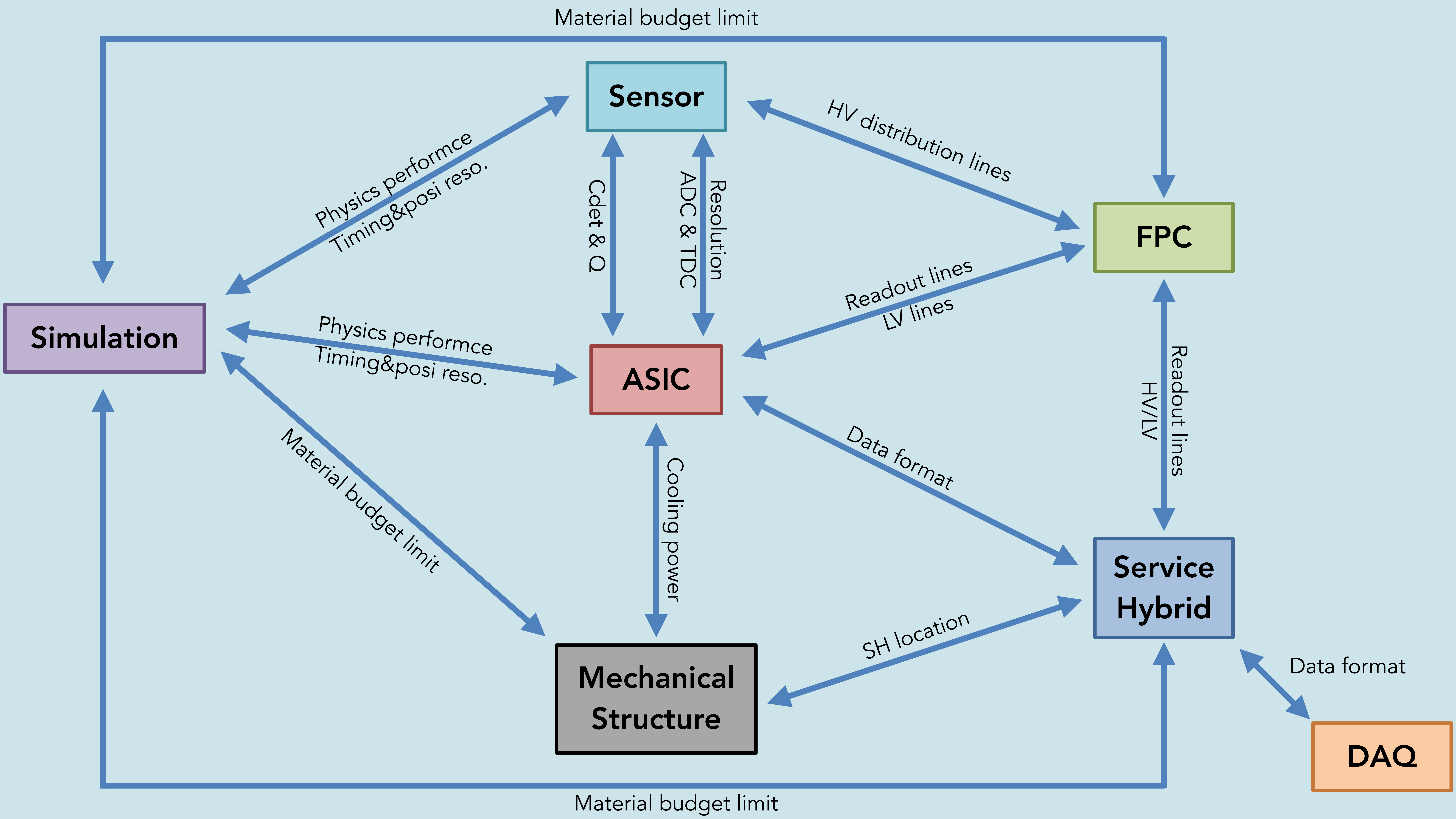


1mmピッチ信号プロファイル





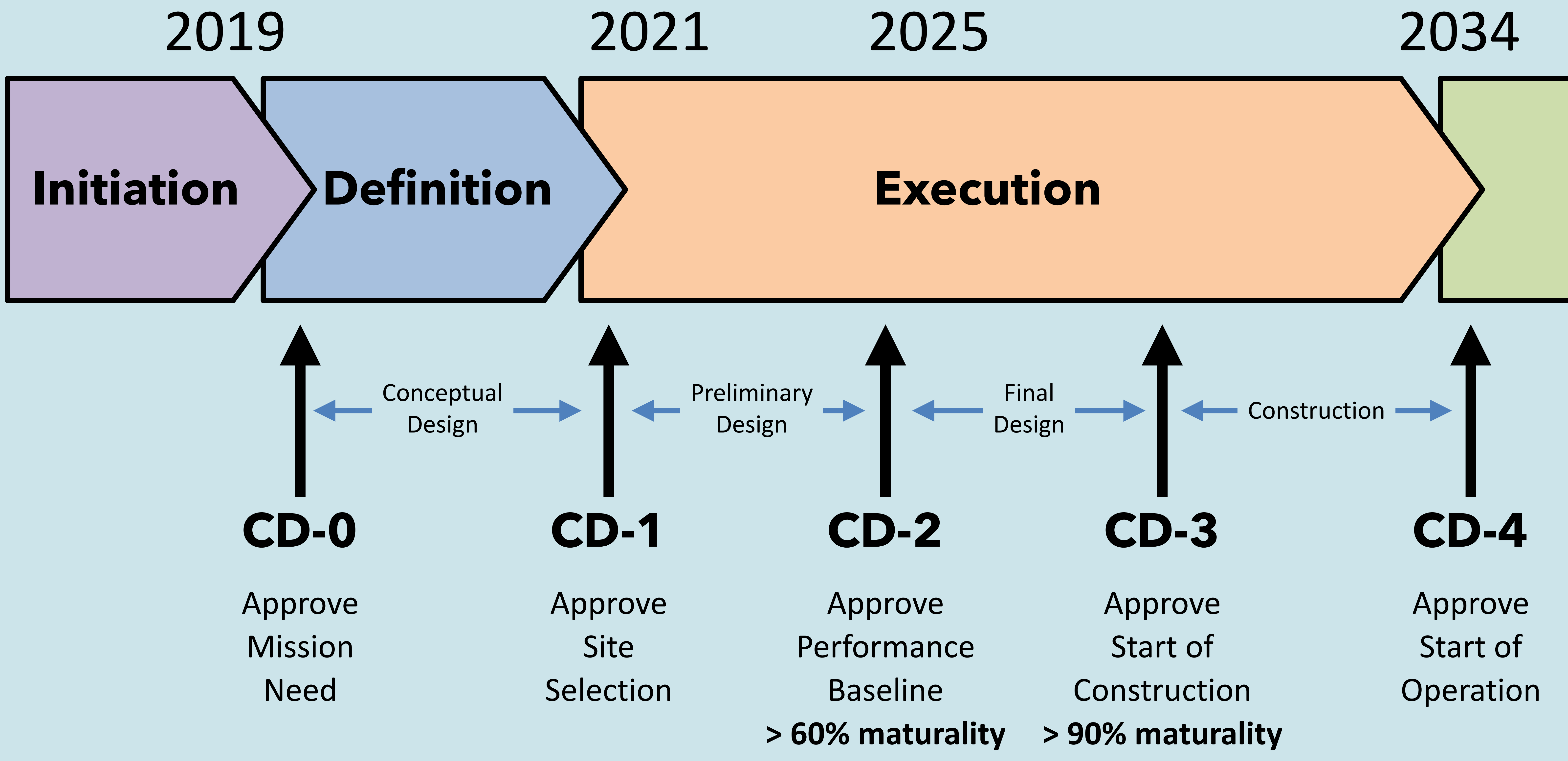
20〜50 μm厚 × 2タイプ電極幾何のセンサーを試作し、時間分解能と位置分解能の評価



Material budget limit
Sensor
HV distribution lines
Physics performce
Timing&posi reso.
Cdet & Q
ADC & TDC
Resolution
FPC
Simulation
Readout lines
LV lines
Physics performce
Timing&posi reso.
ASIC
Readout lines
HV/LV
Material budget limit
Data format
Cooling power
Service Hybrid
SH location
Data format
Mechanical Structure
DAQ
Material budget limit

ePIC and EIC schedule (OLD@March 2023)

EIC Critical Decisions Status and Plans



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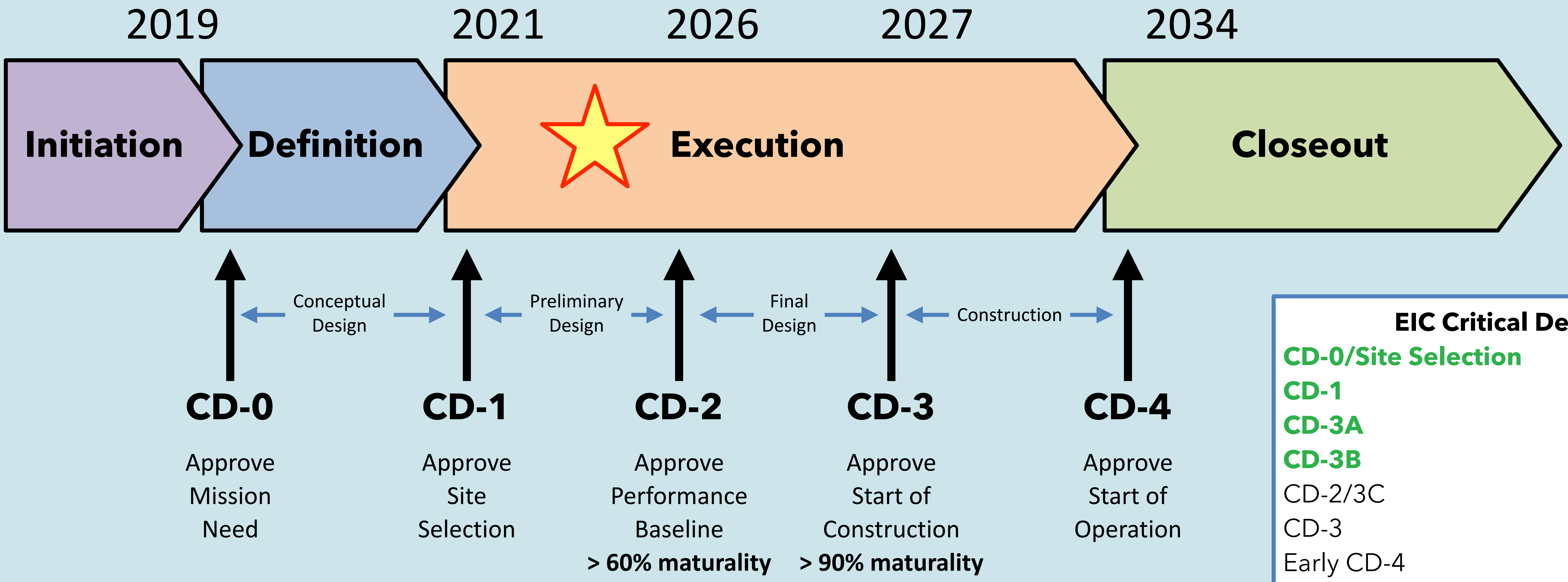
ePIC and EIC schedule (best guess)

EIC Critical Decisions Status and Plans



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CD-4	Q4 FY35

TOF WPs

- Sensor: Simone Mazza (UCSC), Satoshi Yano (HU)
- Frontend Electronics: Wei Li (Rice Univ.)
- Module Integration and Assembly: Mathieu Benoit (ORNL)
- System Tests and Validation: Takashi Hachiya (NWU), Priswish Tribedy (BNL)
- Mechanical Structure: Andy Jung (PU), Yi Yang (NCKU)
- DAQ and Clock: Tonko Ljubicic (RU)
- DCS: Frank Geurts (RU)
- Simulation, Software & Calibration: Kentaro Kawade (SU), Tommy Tsang (KU)