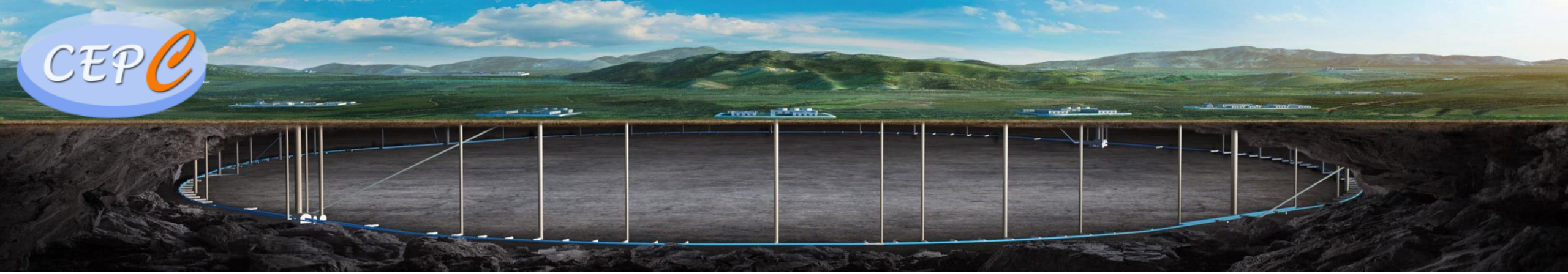

Status of Centimeter Strip AC-LGAD Development

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Motivation：IDRC Comment

- **Comment & Recommendations：**

“Reconsider the size of the AC-LGADs and take both the performance (rate effects, time resolution and achievable position resolution) and expected yield into consideration in order to reach a cost effective solution ”

“The capacitance of some sensors will be large (up to ~10 pF) which will make the noise jitter and rise time such that it will be difficult to achieve the desired time resolution. ”

- **Which size is suitable for our ref-TDR?**

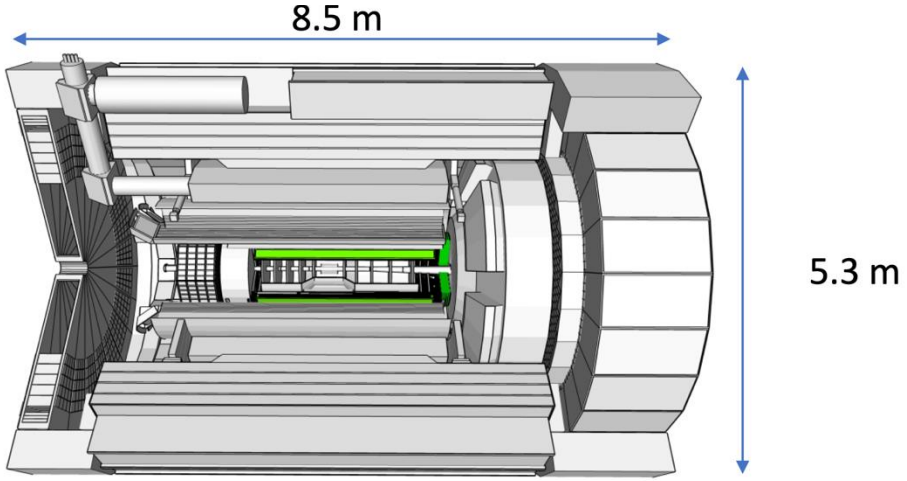
Review the current design status of the centimeter strip AC-LGAD

Current application

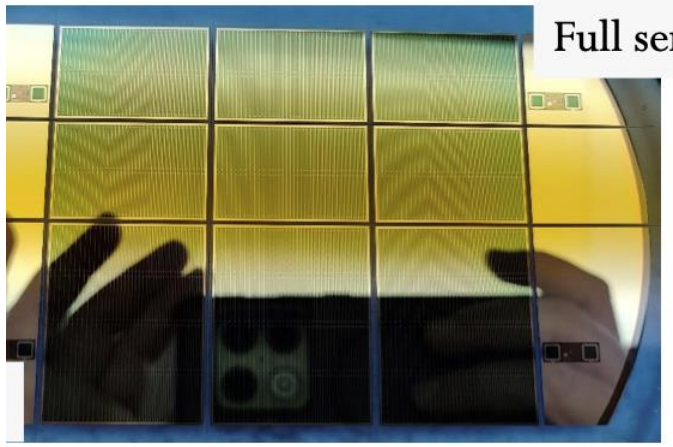
- AC-LGAD would be applied at EIC， also other experiments (such as Pioneer, FCC-ee et all)
  - EIC barrel strip：25/35 ps， 30 μm
  - TOF-PID， tracker

Preliminary Design Report in 2025 for EIC

Subsystem	Area (m^2)	dimension (mm^2)	channel count	timing σ_t (ps)	spatial σ_x (μm)	material budget (X/X_0)
Barrel TOF	12	0.5*10	2.4M	35	30 ($r \cdot \phi$)	3%
Forward TOF	1.1	0.5*0.5	3.2M	25	30 (x, y)	5%



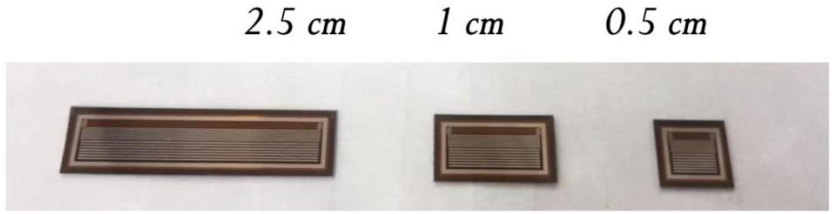
Production in 2024



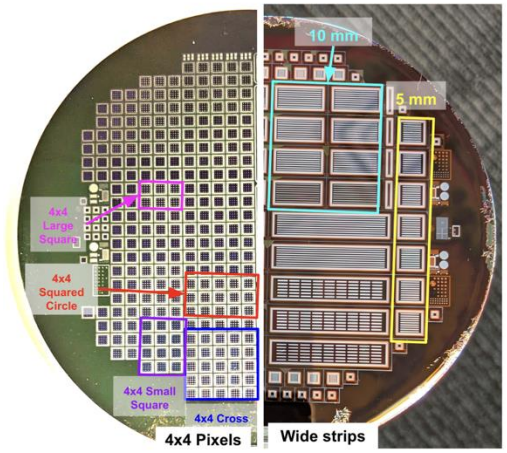
Current strip AC-LGAD study

- A lot study has been done for strip AC-LGAD
- Goal： large area sensors that meet timing/spatial resolution requirements with minimal # of channels
  - CNM、FBK、BNL and HPK
  - Length： 2 mm， 5 mm， 1 cm （baseline） ， 2 cm， 2.5 cm
  - Pitch： 100 μm ， 200 μm ， 300 μm ， 500 μm （baseline）

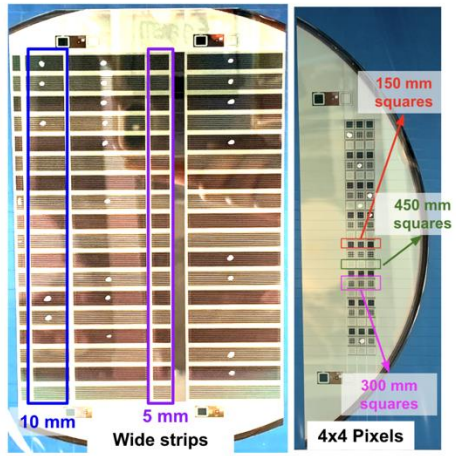
1 cm strip AC-LGAD as baseline



BNL



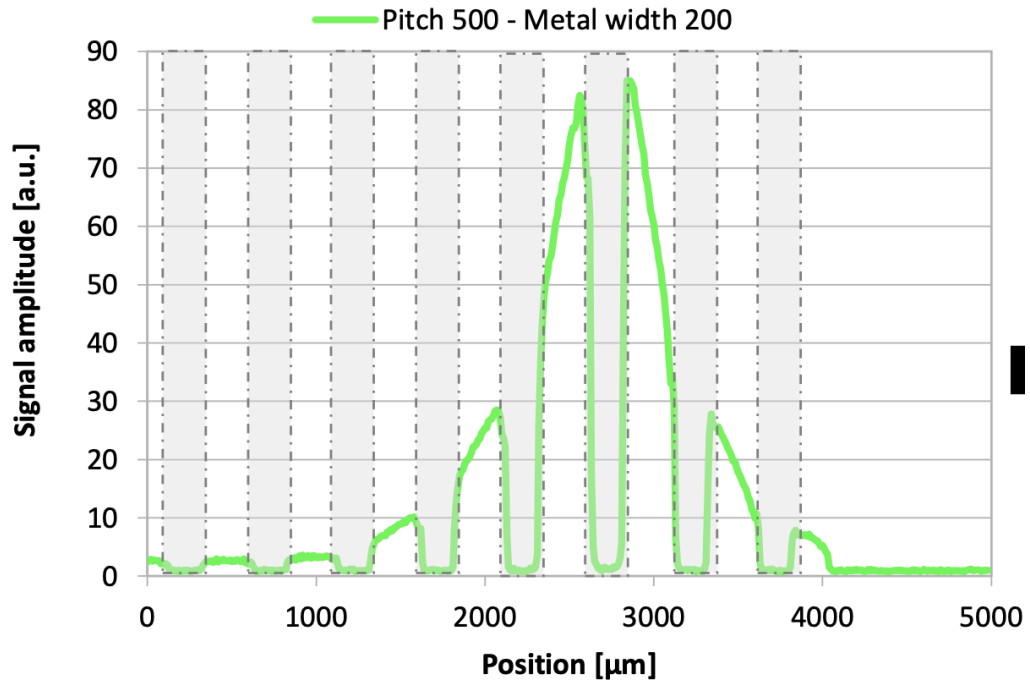
BNL



FBK

Centimeter strip AC-LGAD

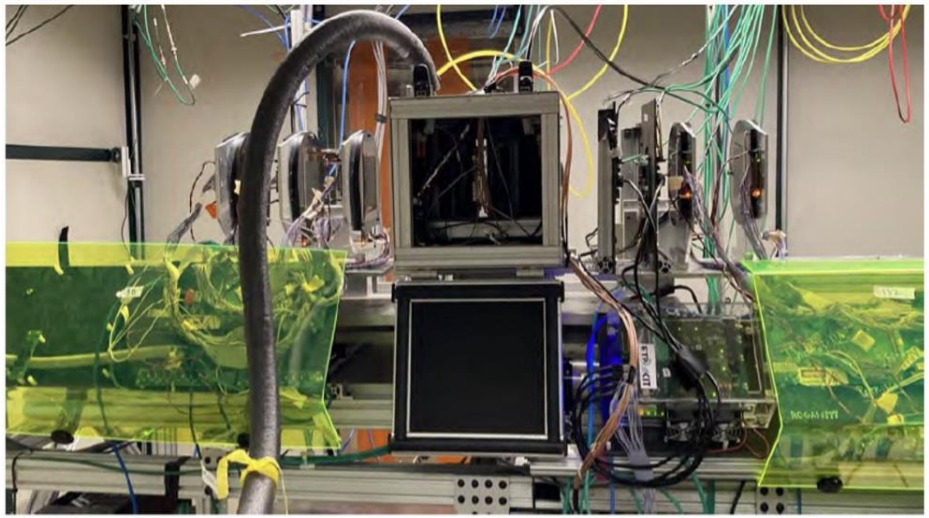
- 1 cm strip AC-LGAD as baseline of EIC ToF and tracker
  - Laser test results： for spatial resolution and charge sharing study
  - Test beam results： efficiency， time resolution， spatial resolution
  - Irradiation campaign

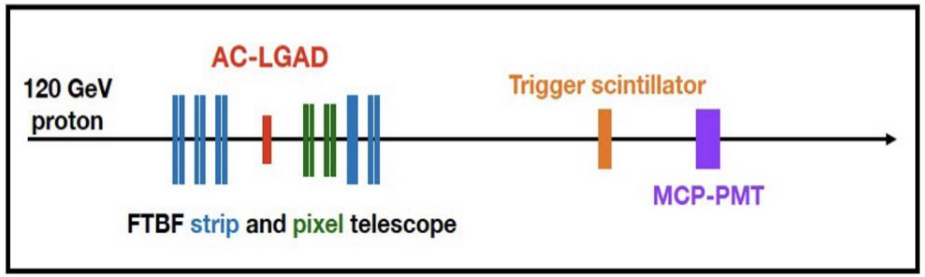


Jeniff et.al. Developments in AC-LGADs for future colliders and nuclear physics experiments

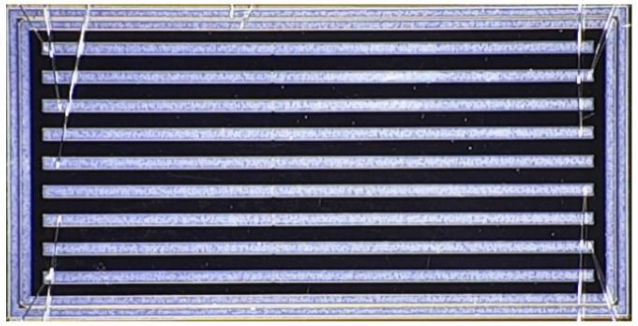
Test beam for 1 cm strip AC-LGAD

Fermilab Test Beam Facility

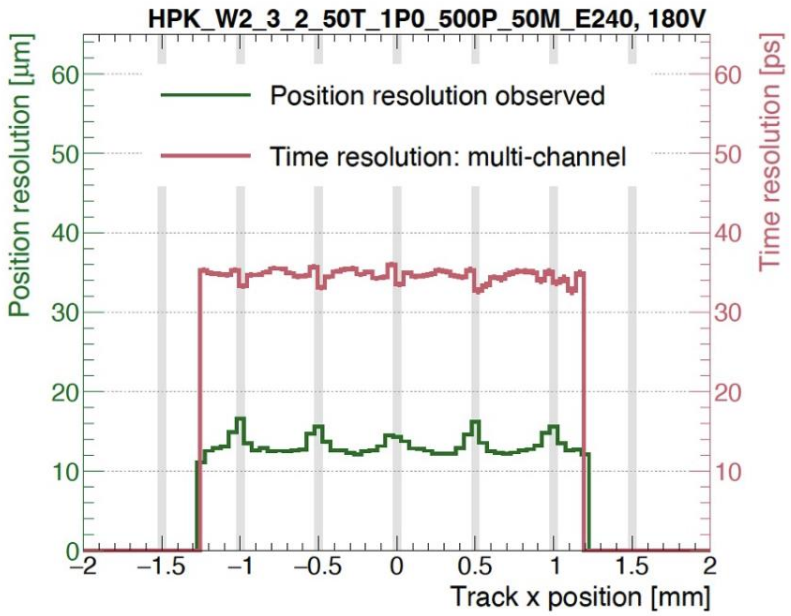




HPK Strip Sensor for BTOF



1 cm long， 500 μm pitch，
50 metal



Time resolution： 35 ps

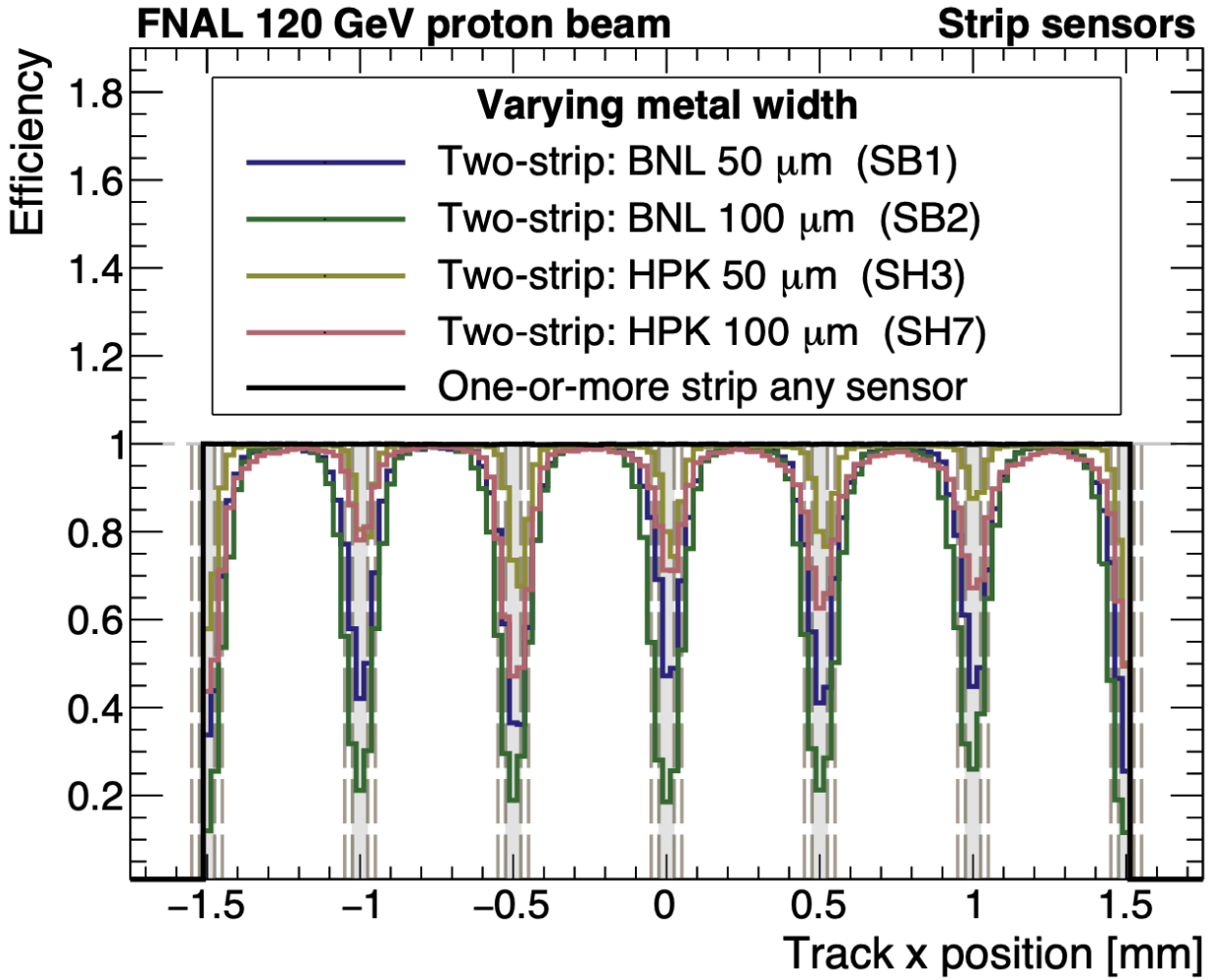
Spatial resolution： 18 μm

will try 1000 μm in the future to reduce the readout channel !

Irene Dutta et.al.
https://arxiv.org/pdf/2407.09928

Efficiency of the Strip AC-LGAD

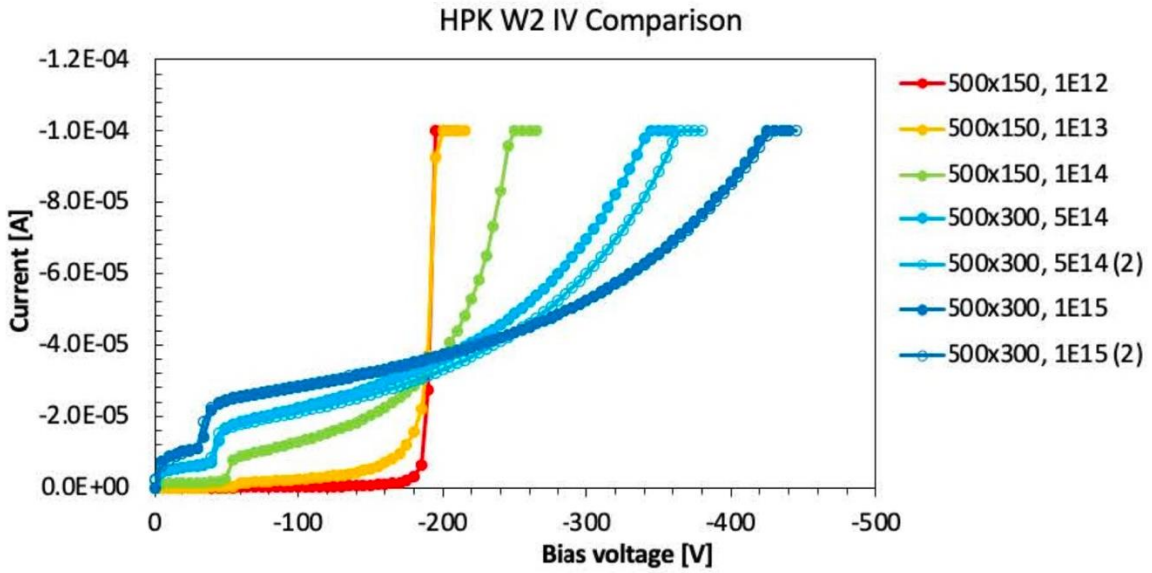
- Combined efficiency: ~98-100% efficiency
  - Efficiency drop under the metal
  - Combining strips would improve ineffciency

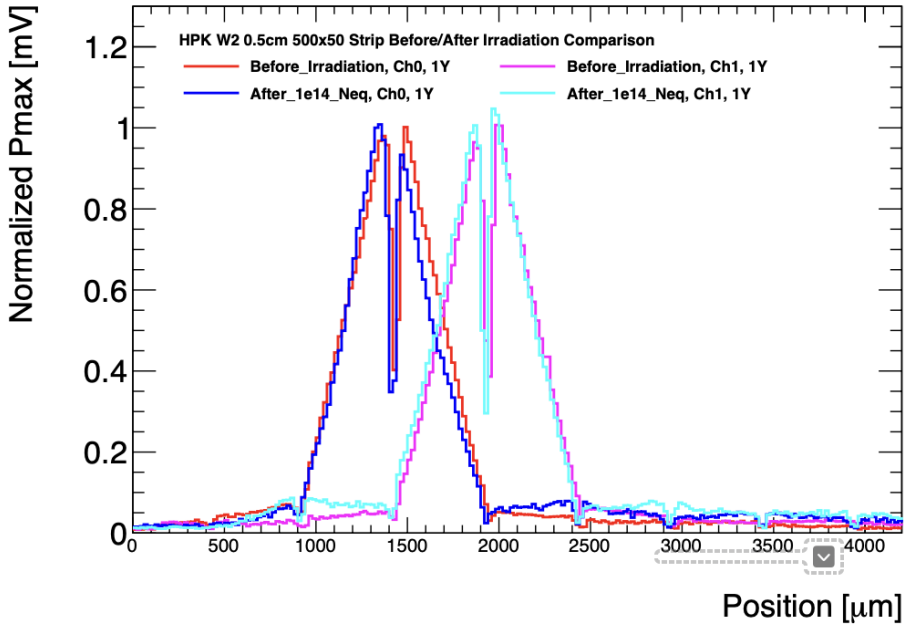


Irene Dutta et.al.
https://arxiv.org/pdf/2407.09928

Irradiation Campaign

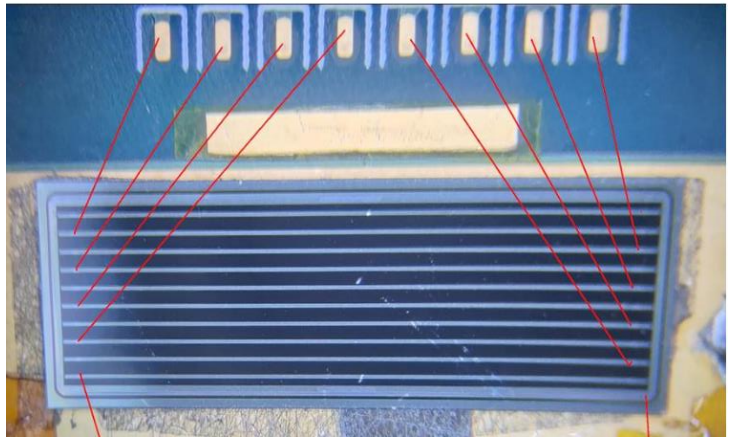
- EIC requirement: 1e12 N_{eq}/cm^2
  - Irradiation up to 5e14 N_{eq}/cm^2
  - No significant change for the gain layer doping up to 1e13 N_{eq}/cm^2
  - No significant change for charge sharing up to 1e14 N_{eq}/cm^2

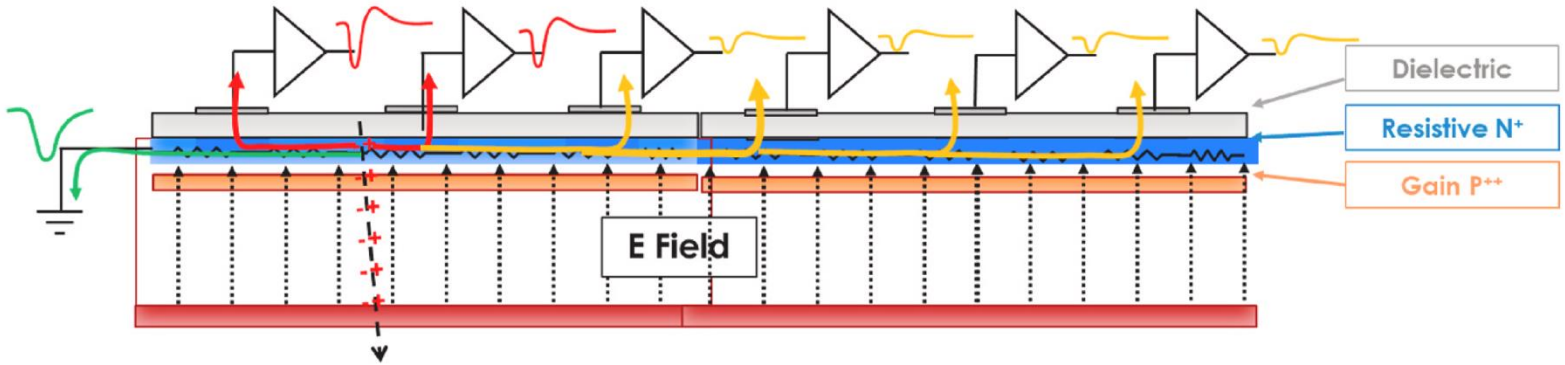




2 cm AC-LGAD problem

- Longer strip：
  - worse time resolution： rise time ↑, Pmax ↓
  - worse charge sharing： length , N+ layer





Jennifer Ott et.al.

2 cm AC-LGAD problem

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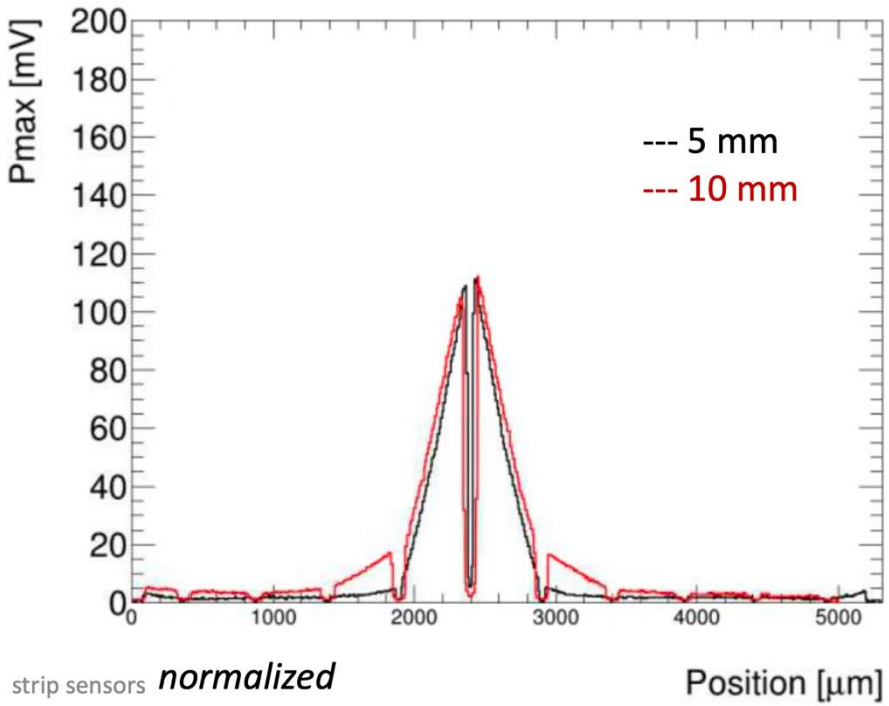


Charge sharing beyond first neighboring strip

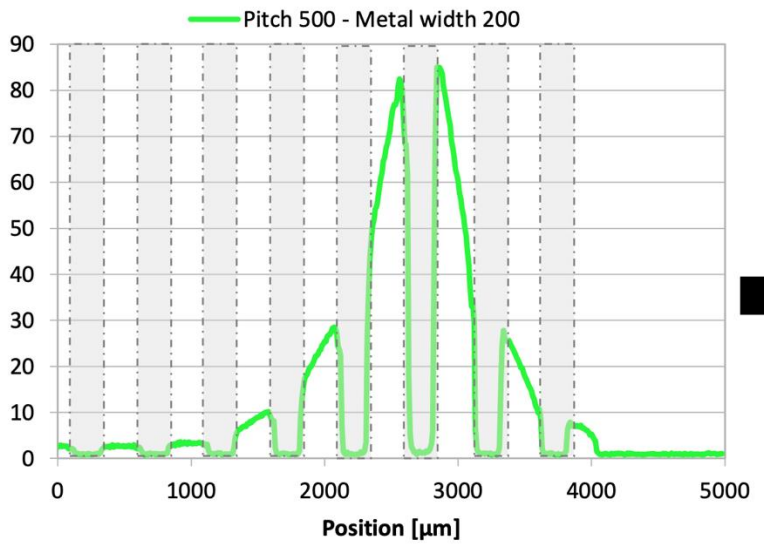
～4.5%

～19%

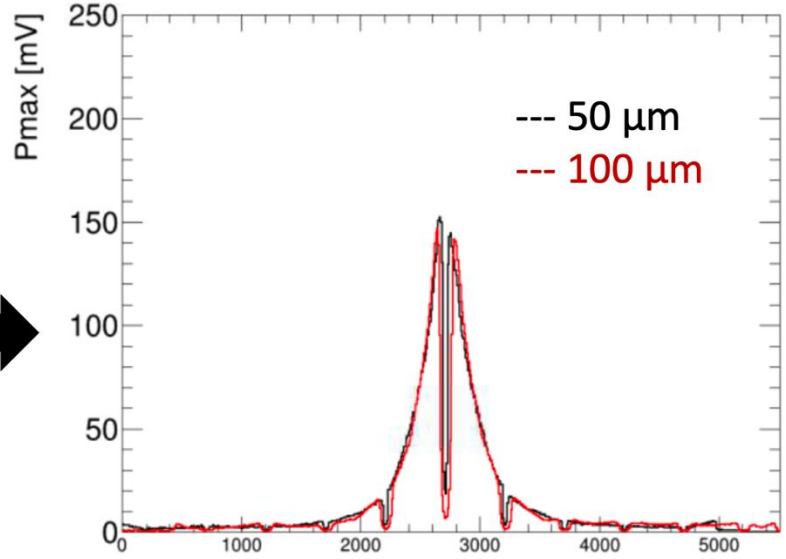
Jennifer Ott et.al.

Charge sharing problem for 2 centimeter AC-LGAD

- Charge sharing for 2 cm centimeter strip AC-LGAD
  - Charge sharing to far-away strips has been the main problem in long strip in the past
- Significant improvement in recent sensors
  - N+ layer tuned
  - Length 2.5 cm -> 2 cm



Older 2.5 cm strip sensor

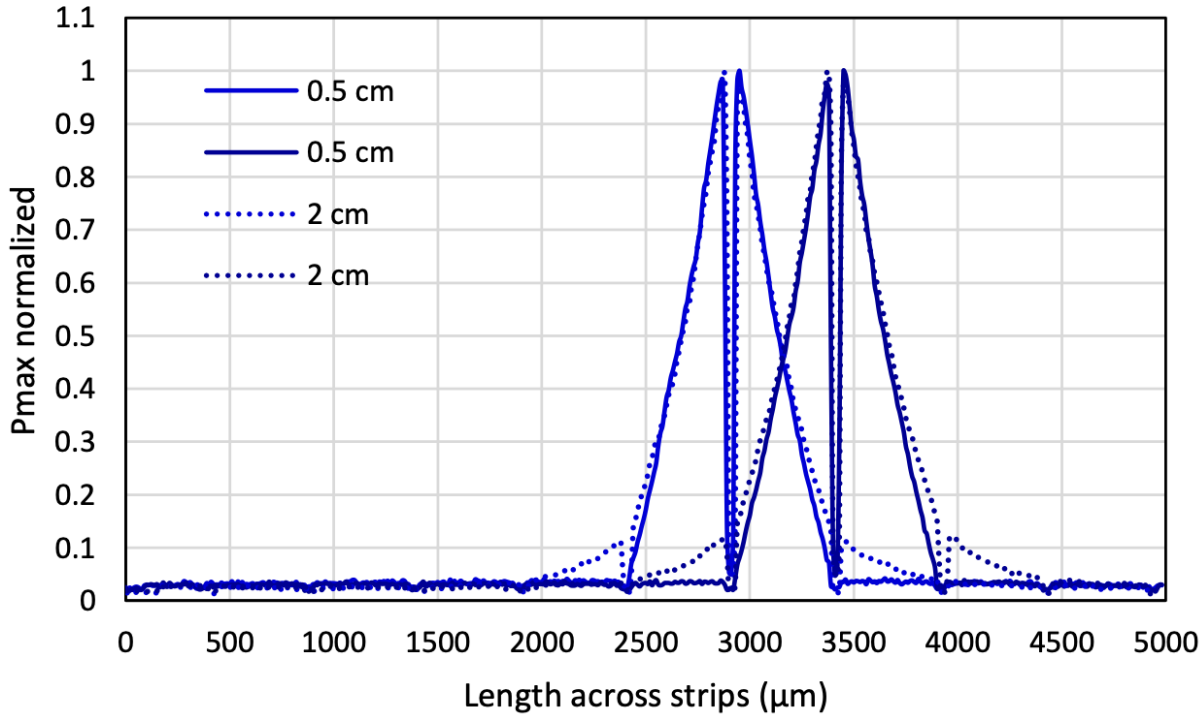


HPK 2 cm strip sensor
Amplitude normalized

[Jeniff et.al. Developments in AC-LGADs for future colliders and nuclear physics experiments]

Charge Sharing Problem Sovled for 2cm

- For HPK E600 type sensors, strip length is indeed confirmed to increase charge sharing with the neighboring strip, however likely **not to a detrimental degree (15% at the next strip)**

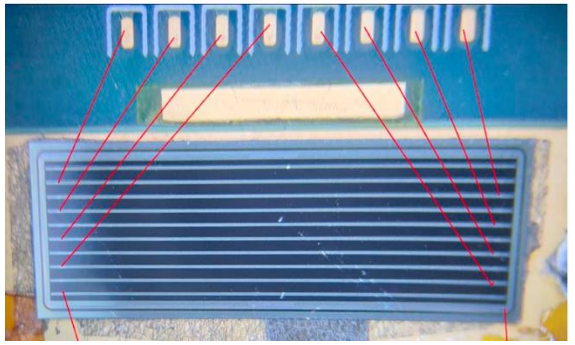


Charge sharing reduced with higher n+ resistivity

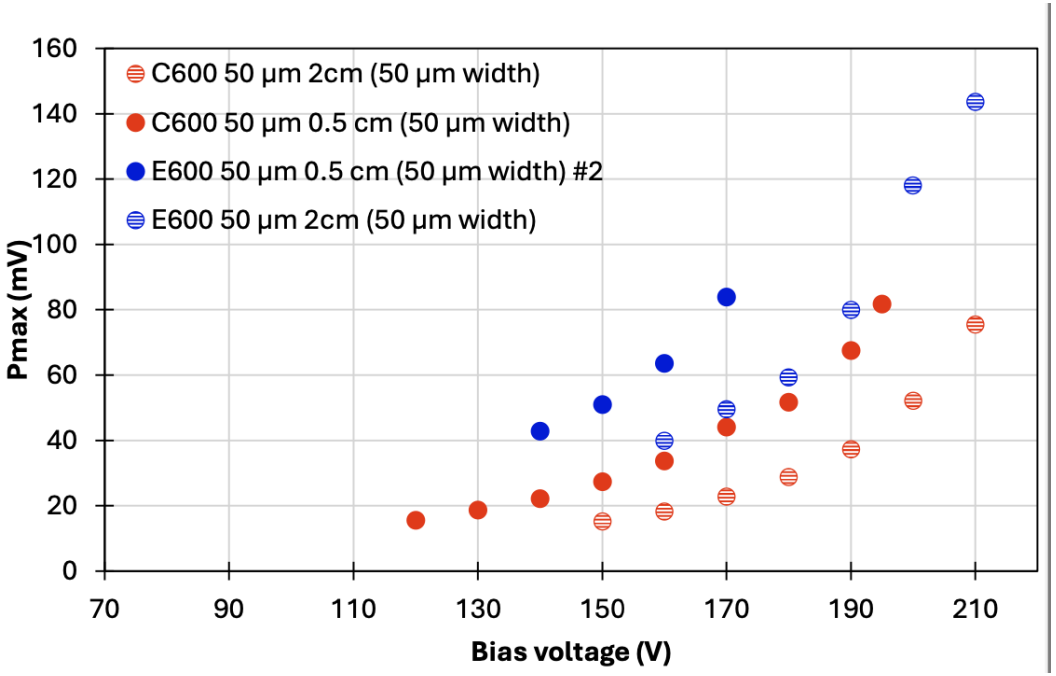
✓ 400 Ω/* -> 1600 Ω/*

2 cm AC-LGAD optimization

- **Time resolution** for the 2 cm AC-LGAD (to be optimized in the future)
  - Pmax ↓ vs Length ↑
  - Rise time to be tested (no available data now)



Higher bias voltage for longer strip

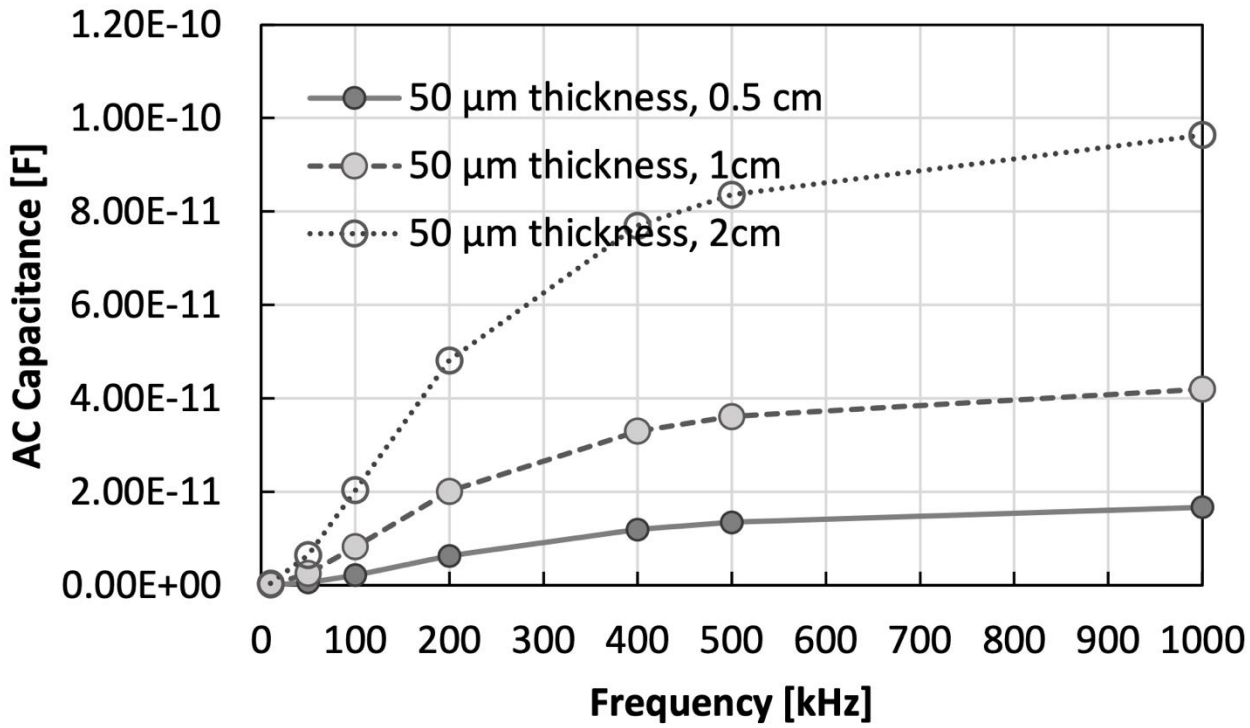


HPK results

In the futre:
Thinner design (20 µm) will improve the time resolution. (FBK plan)

Capacitance to be decided

- Capacitance varies with the frequency： from several pF to hundreds pF
- Capacitance VS length
  - Nearly exponential relation
- rising slower when frequencies increase



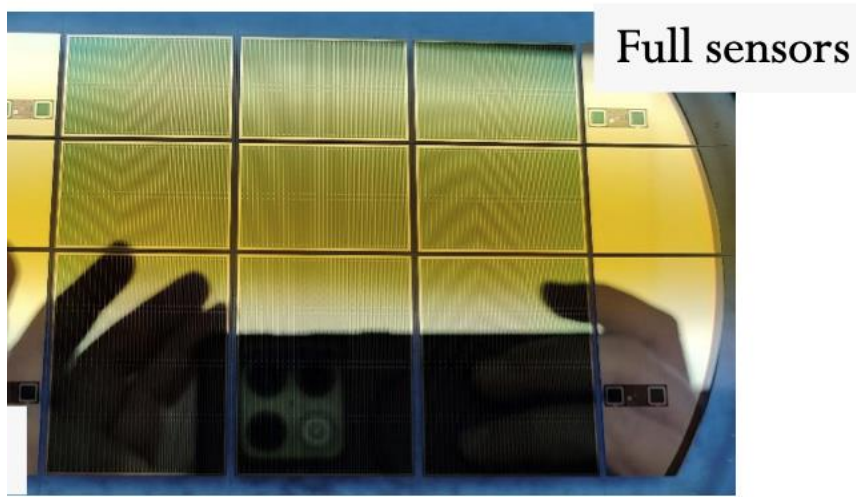
Need to decide which should be the input impendence for the ASIC

- ✓ **Plan to test AC-LGAD with noise measurement method（such with amplifiers， ATLAS Altiroc and domestic ASICs）**

Large AC-LGAD yield

- HPK production for EIC：
- 2.2x3.2 cm with 1cm strip segments （yield ~ 30% oral？ ）
- 4 x 3.2 cm with 1cm strip segments

DRD3 Simone.et.al.



- IME：
- 2x2 cm LGAD （~ 50%） ， 4x4 AC-LGAD （unknow？ Estimated 6.25%）

Conclusion

- **1 cm length strip AC-LGAD： matured in international community**
  - EIC： 35 ps， 30 μm
  - 2.2x3.2 cm with 1cm strip segments， 500 μm pitch
  - Test beam results： 35 ps， 18 μm
  - Efficiency**：～98%- 100%**
  - Meet the requirement of radiation hardness

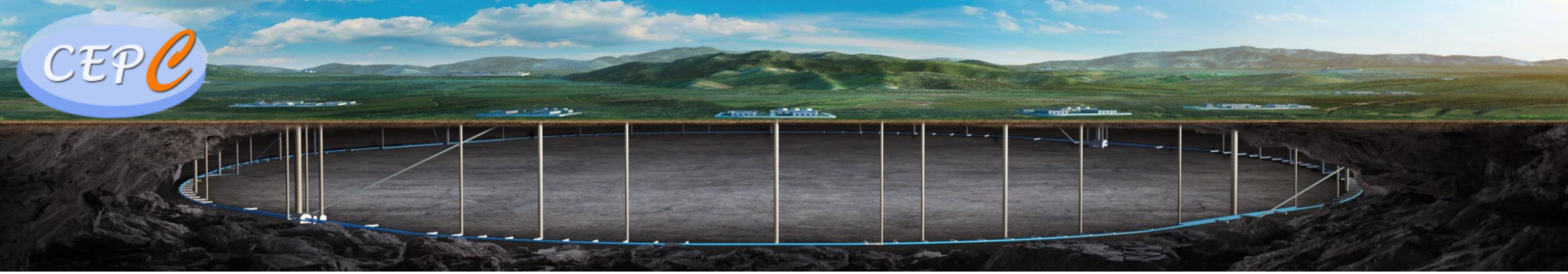
- 2cm length strip: HPK E600 sample
  - **Charge sharing reduced with higher n+ resistivity** （large pitch， high N+）
  - Time resolution need to be optimized: Pmax ,rise time
  - **Yield** : for example 2 x 3 cm，（ <50% from IME ～30%? from HPK AC-LGAD)
  - Capacitance varies with frequency， nearly exponential relation with length

Conclusion

- **Through DRD3 group, cooperated with INFN (Università del Piemonte Orientale)：** **12 samples with 2 cm would be tested**
- 4cm length strip： 4 cm x 5 cm strip （OTK Baseline in ref-TDR)
  - **Yield （estimated to be ~6% from IME LGAD， ~0.8% from HPK? ）**
  - **No tested data**
  - **Power consumption will increase。。。。**
  - **Sample available until the mid of next year**

Plan

- **Plan：**
  - larger pitch
  - Optimize the rise time and Pmax
  - Decide the input capacitance: noise measurement， to be tested with ASIC



Thank you for your attention!

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