Performance of High granularity readout TPC for CEPC TDR

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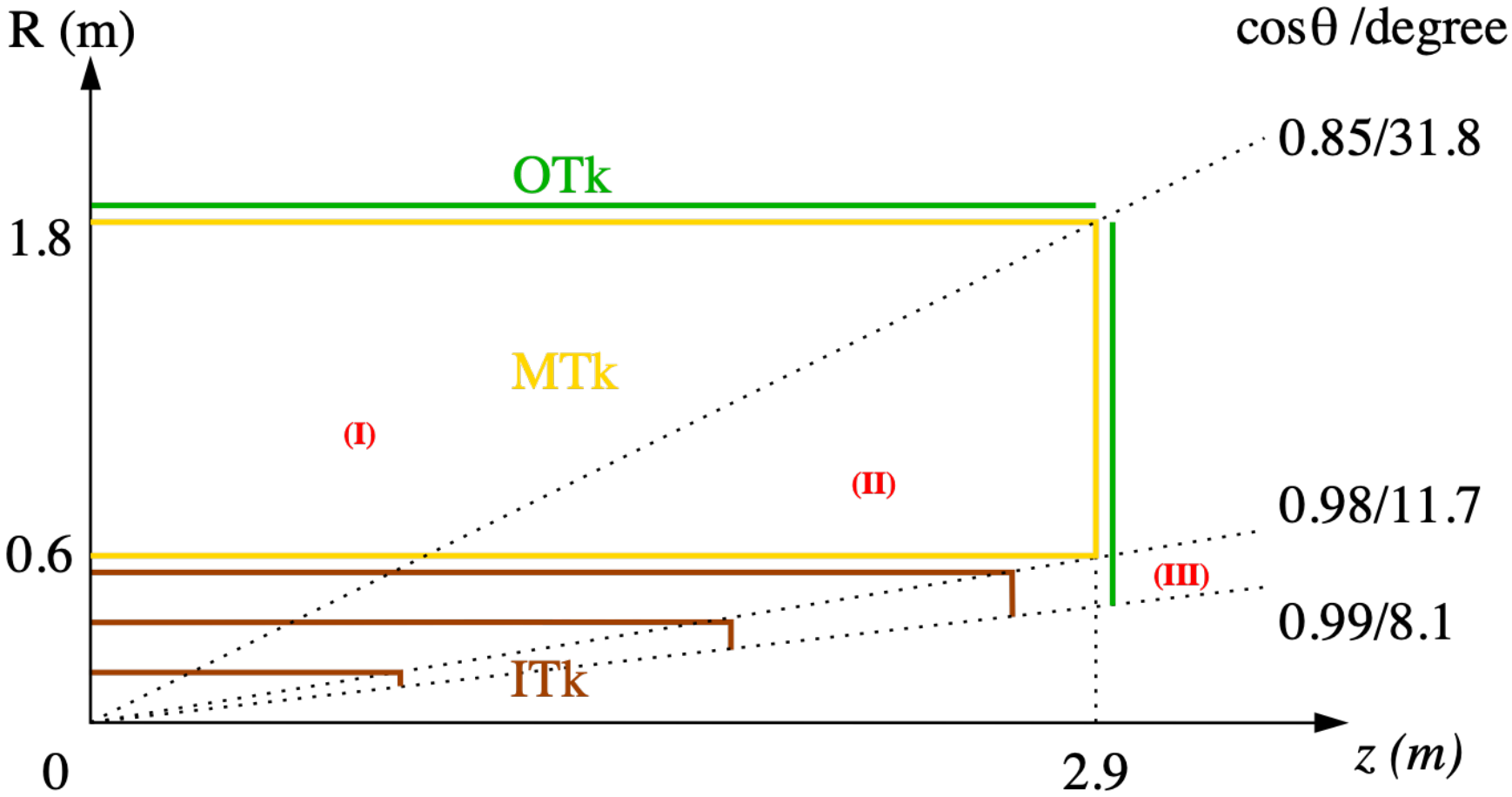
- **High granularity readout TPC as the main track**

Track detector system in CEPC Phy.&Det. TDR

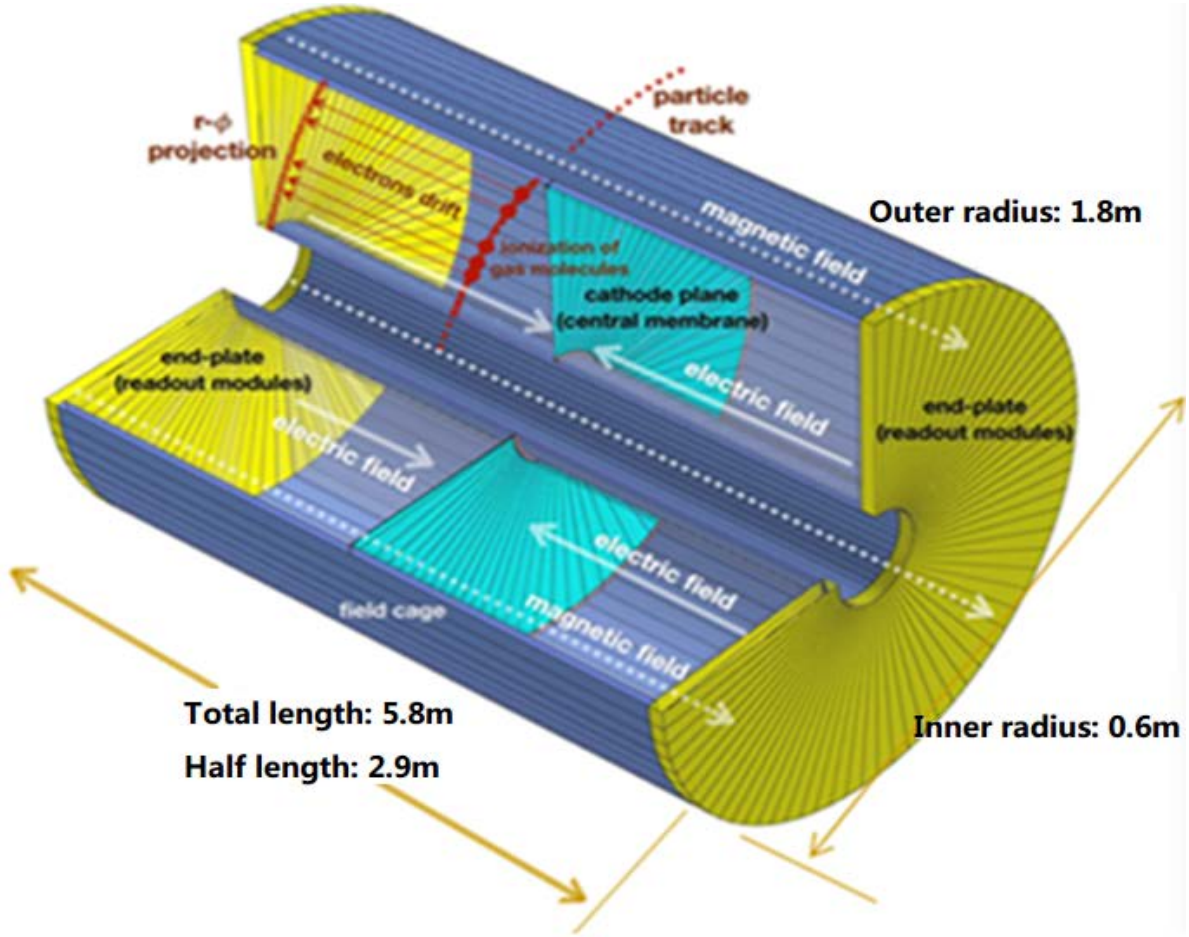
- The track detector system's geometry was finalized.
  - Converging geometries as quickly as possible in preparation for physics simulation
  - Geometry diagram from the slides on Tuesday in this week



Almost finalized Geometry of the track detector system

TPC detector in CEPC Phy.&Det. TDR

- General geometry of TPC and the optimization modules in endcap
  - Some discussion with Quan Ji and Jian Zhang



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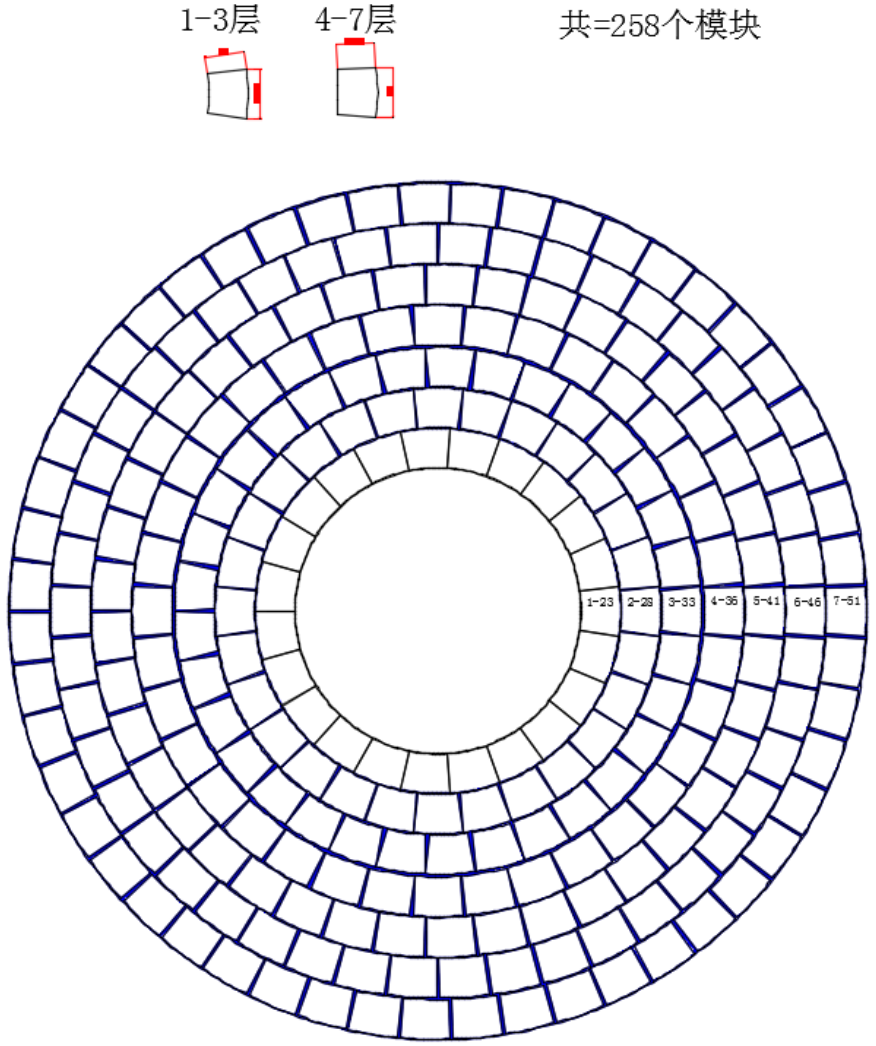


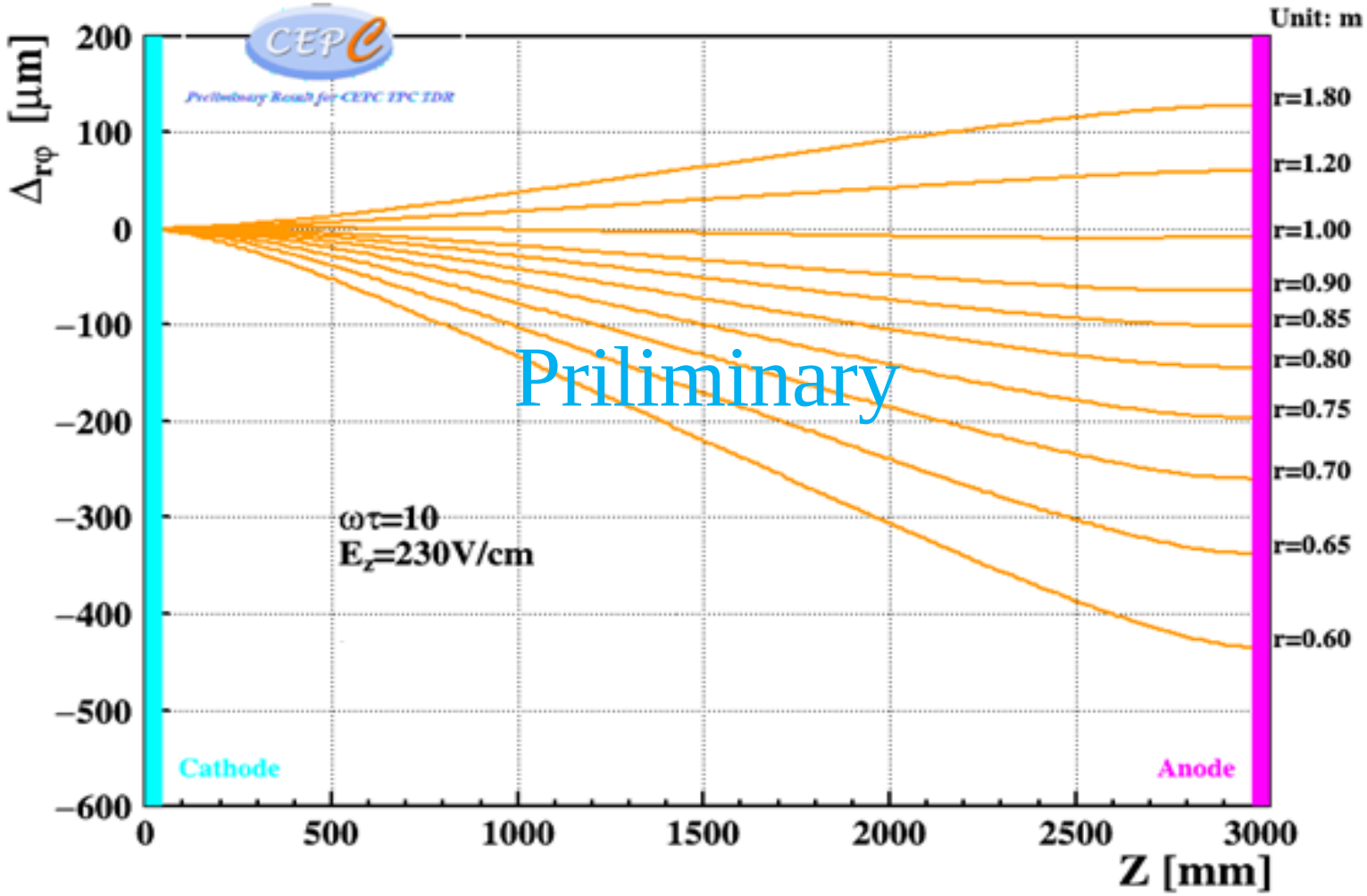
Almost finalized Geometry of TPC detector and the Endplate

高粒度时间投影室 High granularity readout TPC @cosθ≃0.98

Parameters	Higgs run	Z pole run
B-field	3.0T	2.0T
Pad size (mm)/All channels	0.5mm×0.5mm /2×3×10^7	0.5mm×0.5mm /2×3×10^7
Material budget barrel	≃ 0.012 X_0	≃ 0.012 X_0
Material budget endcap	< 0.20 X_0	< 0.20 X_0
Points per track in rφ	2200	2200
σ_{point} in rφ	≤ 100μm (full drift)	≤ 300μm (full drift)
σ_{point} in rz	≃ 0.1 – 0.5 mm (for zero – full drift)	≃ 0.4 – 1.0 mm (for zero – full drift)
2-hit separation in rφ	< 0.5mm	< 0.5mm
K/π separation power @20GeV	≤ 3σ	≤ 3σ
Momentum resolution normalised: $\sigma_{1/pT} = \sqrt{a^2 + (b/pT)^2}$	a = 1.82 e -5	a = 3.32 e -5
	b = 0.60 e -3	b = 0.92 e -3

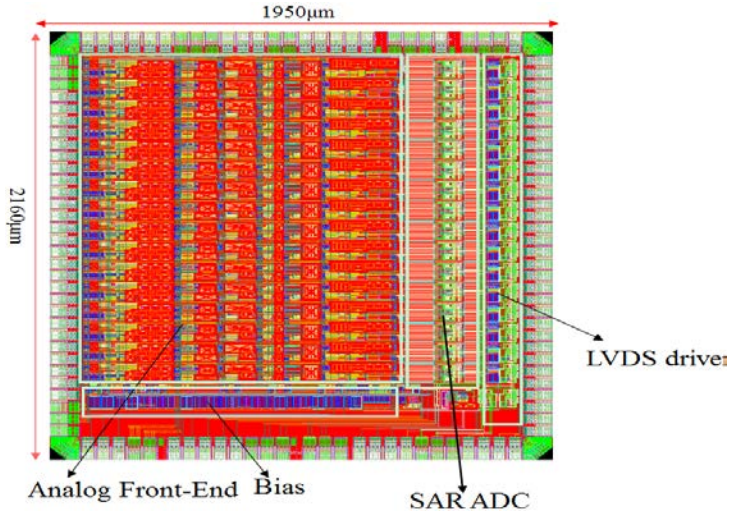
Maxim distortion calculation using new geometry

- **Using the maxim ions in chamber similar to ALICE TPC**
  - **Large radius (0.6m) in CEPC TPC will be smaller, if any, correction will be needed.**



Power Consumption – TPC - Validation

- **Power consumption**
  - Pad readout TPC@1mm×6mm@IHEP
  - Total channels: 10^6
  - High granularity readout TPC： 3×10^7
  - Total power: <10 kW
    - <100mW/cm^2
    - WASA ASIC chip: 3.5mW/ch@40 MS/s

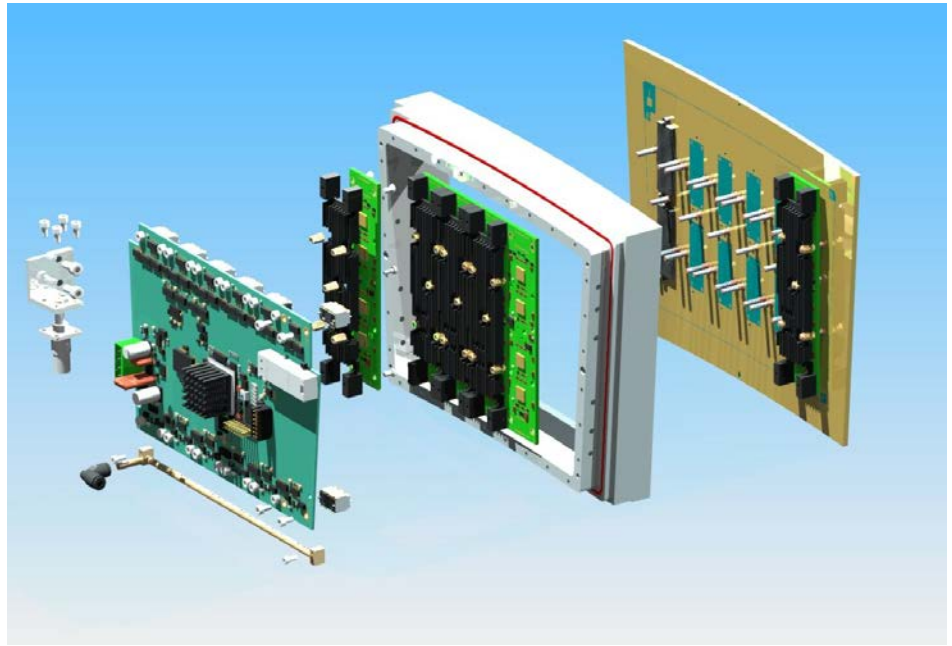


	AGET	PASA+ALTRO	Super-ALTRO	SAMPA
TPC	T2K	ALICE	ILC	ALICE upgrade
Pad尺寸	6.9x9.7 mm^2	4x7.5 mm^2	1x6 mm^2	4x7.5 mm^2
通道数	1.25 x 10^5	5.7x 10^5	1-2 x 10^6	5.7 x 10^5
读出结构	MicroMegas	MWPC	GEM/MicroMegas	GEM
增益	0.2-17 mV/fC	12 mV/fC	12-27 mV/fC	20/30 mV/fC
成型方式	CR-(RC)^2	CR-(RC)^4	CR-(RC)^4	CR-(RC)^4
达峰时间	50 ns-1us	200 ns	30-120 ns	80/160 ns
ENC	850 e @ 200ns	385 e	520 e	482 e @ 180ns
波形采样方式	SCA	ADC	ADC	ADC
采样率	1-100 MSPS	10 MSPS	40 MSPS	10 MSPS
精度	12 bit(external)	10 bit	10 bit	10 bit
功耗	<10 mW/ch	32 mW/ch	47.3 mW/ch	17 mW/ch
CMOS工艺	350 nm	250 nm	130 nm	130 nm

- **Power consumption and FEE cost**

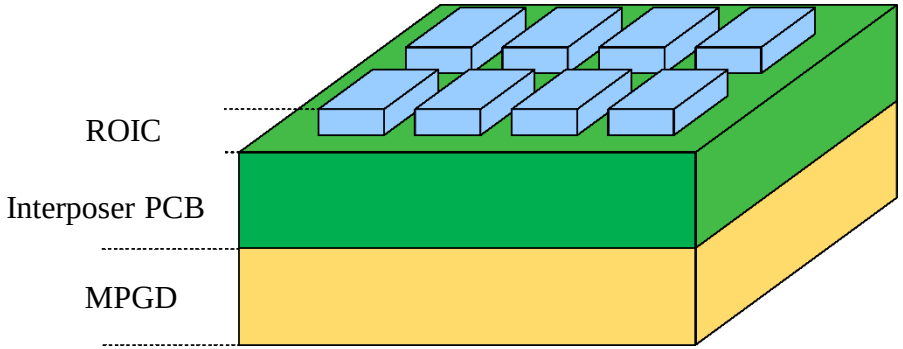
Modular Readout

- Power consumption
  - Limit: <10 kW/endplate ~ 58.82 W/module ~14.71 W/FEE board
  - 1.8/2.5V, 180 nm (optional 130nm for better performance)
- Avg. data bandwidth (raw data)
  - 80 particles/BX, 12,000 hit/particle, 32(48)b/hit
  - 1 Endplate: 1.228(1.843) Tbps @ 40M BX
  - 1 Module: 4.873(7.314) Gbps
  - 1 FEE board: 1.218(1.829) Gbps



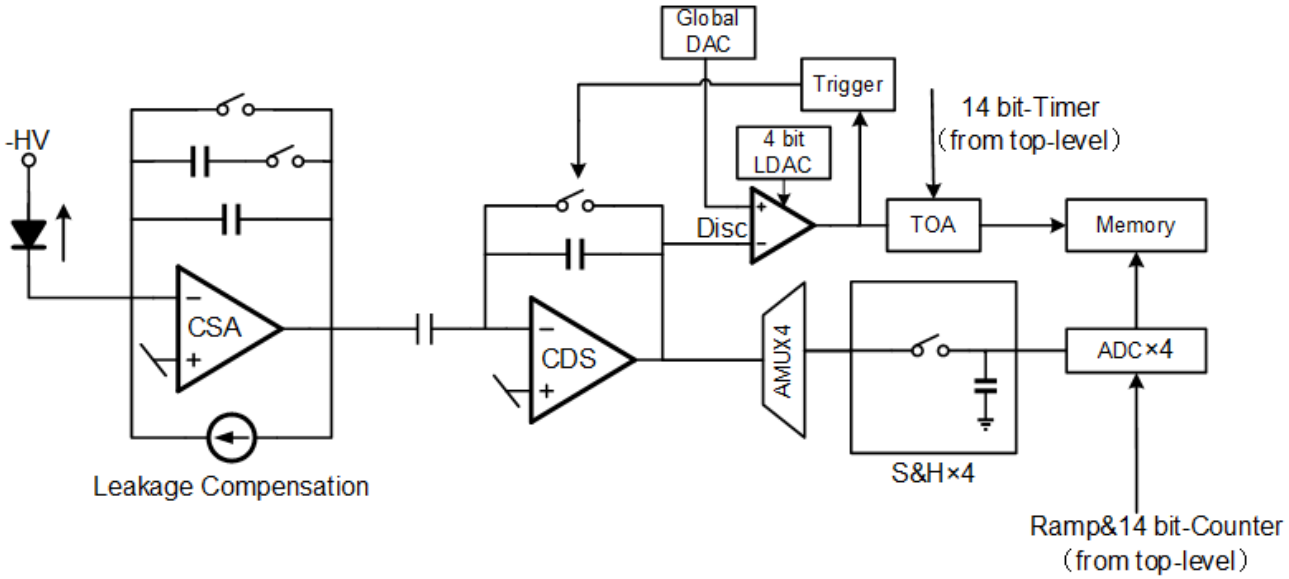
FEE: sub-module

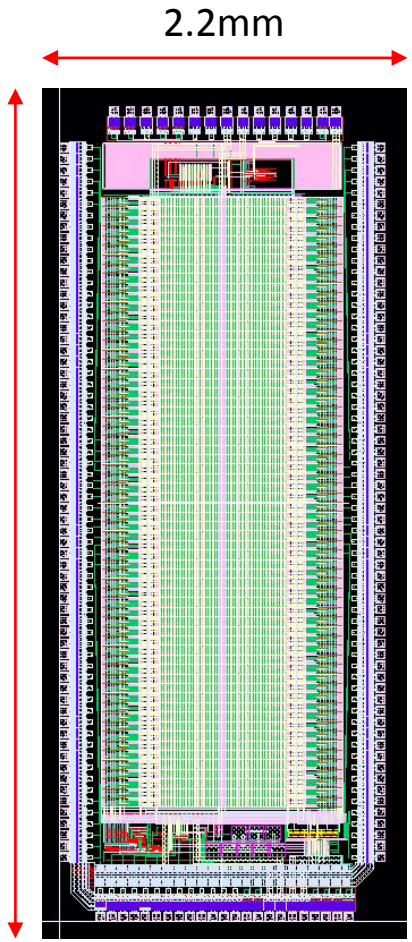
- Concept R&D design
  - ROIC +Interposer PCB as RDL
  - High metal coverage, 4-side buttable
  - Low power Energy/Timing measurement ASIC
    - ~100 e noise
    - 5 ns drift time resolution
    - **100 mW/cm^2 (250uW/ch) ~ 35.7 W/module ~ 6.069 kW/endplate**



FEE: pixel ROIC

- Charge Sensitive Preamplifier(CSA)
- CDS amplifier provides additional gain and noise shaping
- 14-bit Wilkinson type ADC each pixel
- Timing discriminator with14-bit TOA (Time of Arrival) information





TPC FEE cost

Items	Unit	Unit cost (RMB)	Quantity	Total cost (10k RMB)
FEE ASIC	ch	0.4	60,000,000	2400.00
Connector	pair	200	10,000	200.00
Cables	piece	500	1,000	50.00
Total				2650.00

Some further information and discussion

- Optimization performance of the reasonable readout TPC
  - PID requirements for both Higgs physics and Z-physics
  - All estimates should be based on available pixelated readout TPC techniques
    - Power consumption relative with the high granularity readout
    - Amount output detector data relative with the high granularity readout
- Need the new geometry beam background simulation data to input TPC from MDI group
- Need the new geometry cumulative radiation dose data to input FPGA estimation

- LCTPC collaboration will give some contributions to CEPC Phy.&Det. TDR
    - The LCTPC Collaboration meeting will be held next week (12^{nd} -14^{th})

Some further information and discussion

- Cite#1 https://doi.org/10.1088/1748-0221/12/07/P07005
- Cite#2 Correcting for Distortions due to Ionization
- Cite#3 Occupancy in the CLIC
- Cite#4 https://doi.org/10.1088/1748-0221/12/07/P07005
- Cite#5 GridPix detectors
- Cite#6 Low power WASA chip
- Cite#7 Cost estimation of ILD concept
- Cite#8 https://agenda.linearcollider.org/event/5504/contributions/24543/attachments/20144/31818/PositiveIonEffects-kf.pdf
- Cite#9 https://indico.fnal.gov/event/46746/contributions/208077/attachments/141125/177798/LCTPC.pdf
- Cite#10 Di Meglio, Alberto, et al. CERN Quantum Technology Initiative Strategy and Roadmap. No. CERN-OPEN-2021-012. 2021
- Cite#11 arXiv:1902.01987 [physics.ins-det, 2019] Yuan, Zhiyang, et al. International Journal of Modern Physics A 36.22 (2021): 2142015.
- Cite#12 Chang, Y., et al. "Performance of the continuous ions suppression TPC prorotype for circular collider." Journal of Instrumentation 15.09 (2020): C09065.

Many thanks!