高粒度时间投影室读出数据讨论

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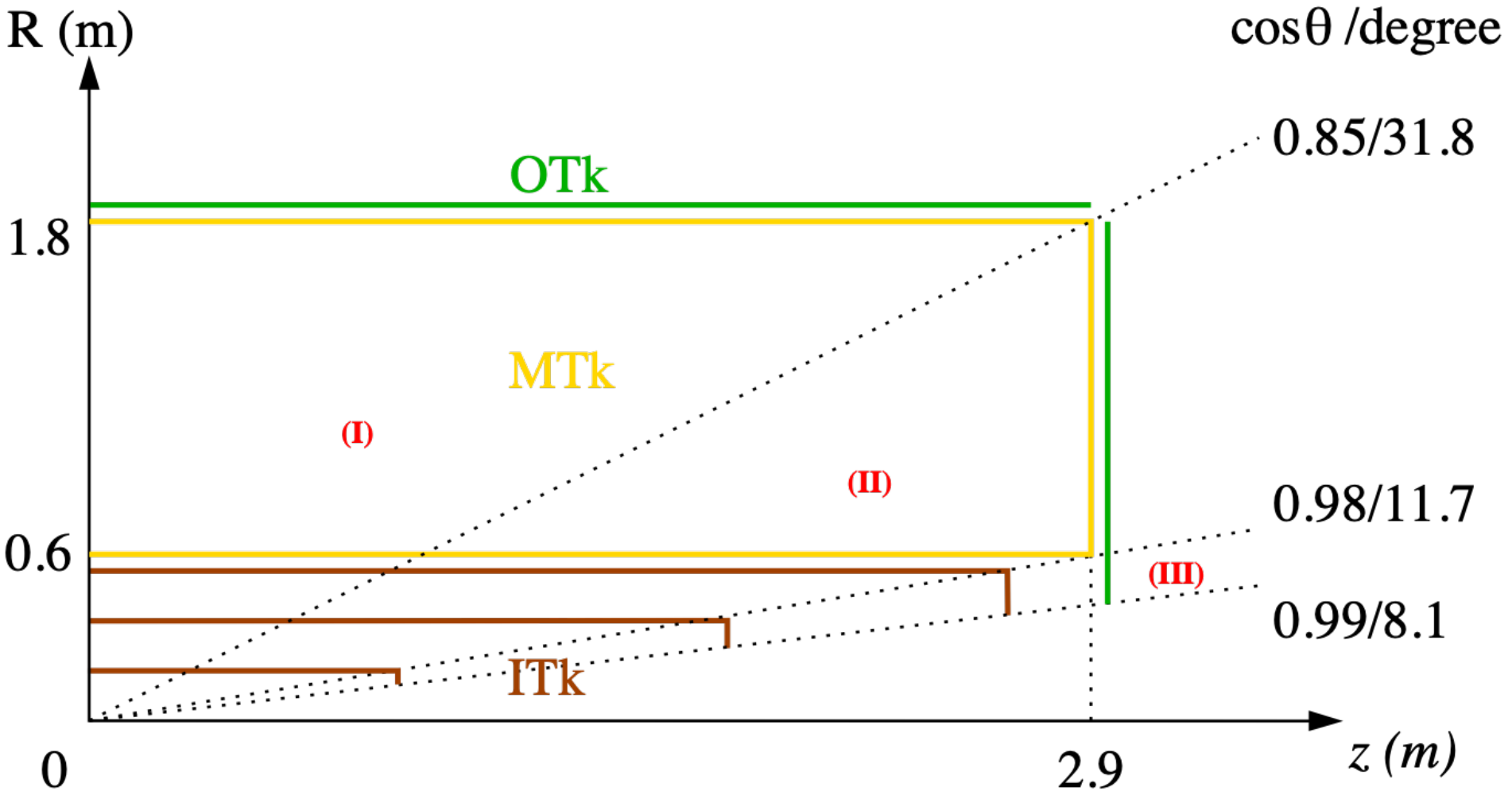
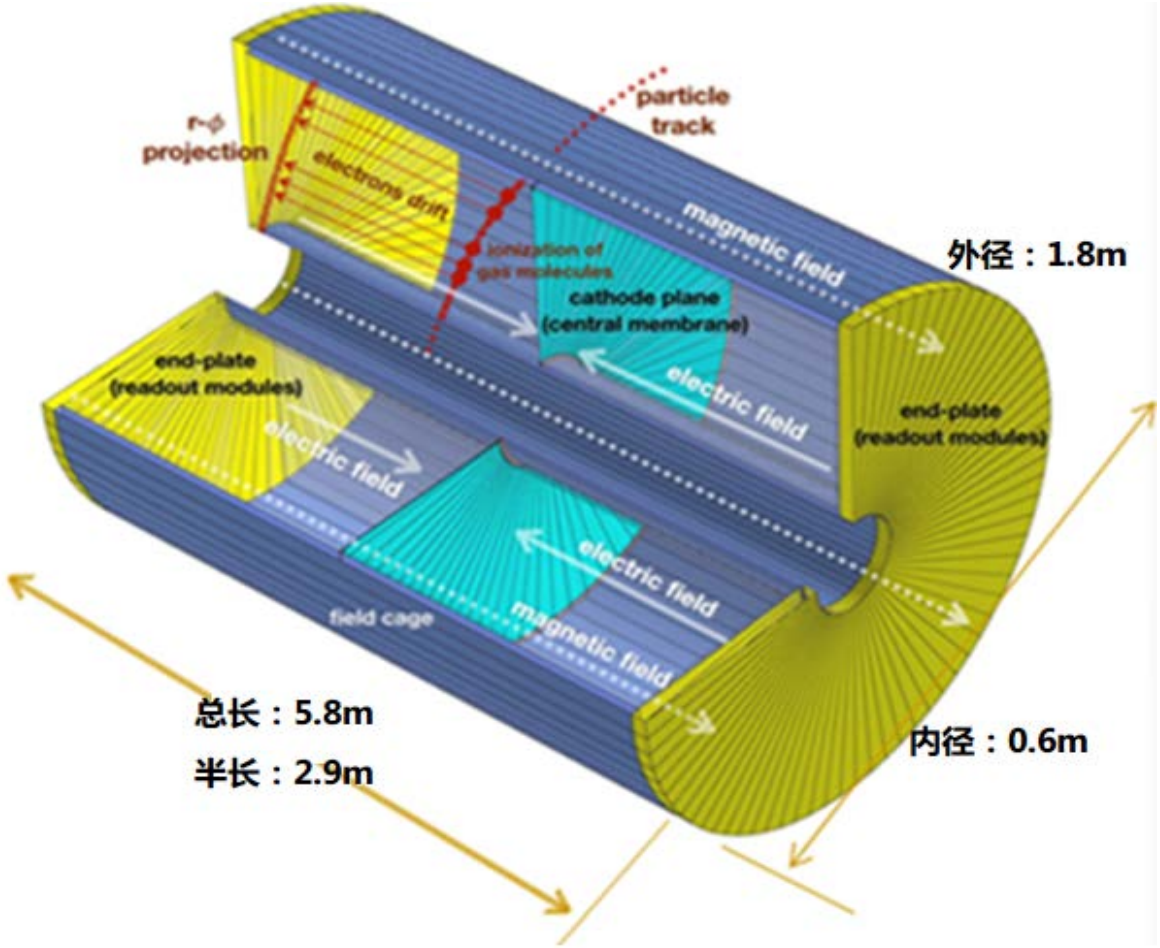
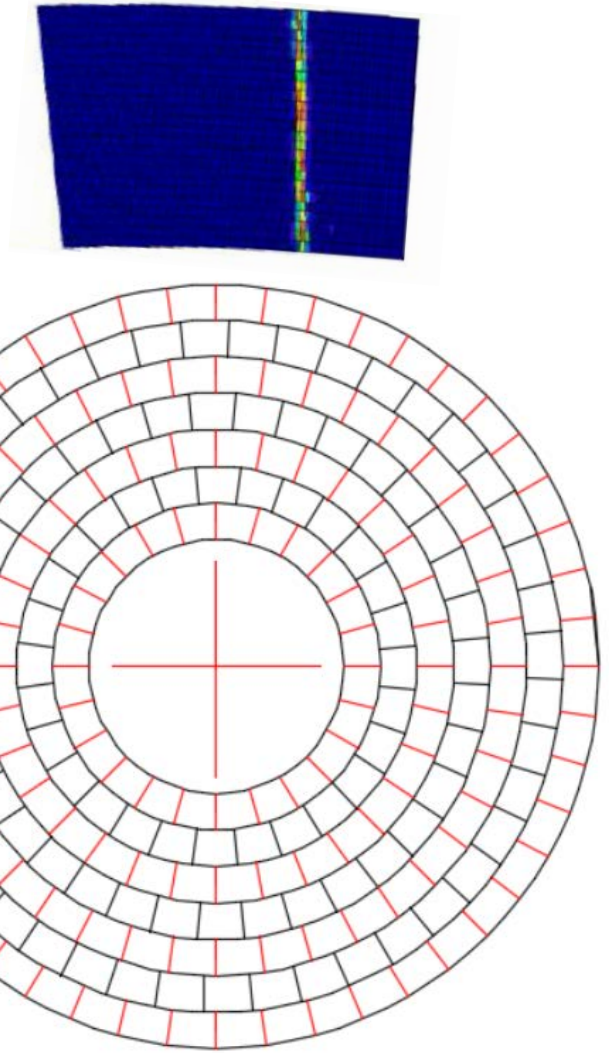
- 高粒度时间投影室

Track detector system



Tasks of TPC R&D for CEPC TDR





总体图及端盖模块示意图（总共252个模块，每个读出模块：21cm×17cm）

高粒度时间投影室 -1 @cosθ≃0.85

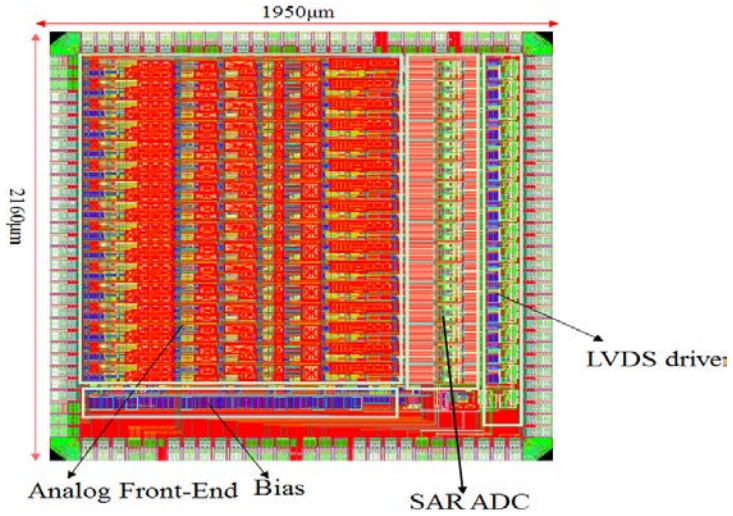
Parameters4	Higgs run	Z pole run
B-field	3.0T	2.0T
Pad size (mm)/All channels	1.0mm×6.0mm /2×10^6	1.0mm×6.0mm /2×10^6
Material budget barrel	≃ 0.012 X_0	≃ 0.012 X_0
Material budget endcap	< 0.17 X_0	< 0.17 X_0
Points per track in rφ	200	200
σ_{point} in rφ	≤ 100μm (full drift)	≤ 500μm (full drift)
σ_{point} in rz	≃ 0.4 – 0.8 mm (for zero – full drift)	≃ 0.5 – 1.5 mm (for zero – full drift)
2-hit separation in rφ	< 2mm	< 2mm
dE/dx	≤ 3.6%	≤ 3.6%
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

高粒度时间投影室 -2 @cosθ≃0.85

Parameters4	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

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

可参考的数据量

Reference info from ALICE TPC / STAR TPC (in operation) and ILD TPC (future)

- **Pads TPC (example)**
  - There are average 80 particles/ BX. Each particle produces 600 channels of signal. The noise rate is 10^-4/ BX / channel. Thus the number of channels with hit (signal & noise) = 80*600 + (840K-80*600) *10^-4= 48K/ BX.
  - Preliminary estimation of raw data size : Data will be zero-suppressed at each ASIC. There are some initial information of 2-byte header whether or not the ASIC has any hit. For each hit we use a 7-bit channel ID, and 9-bit ADC, i.e. 2 bytes / hit. So the useful data rate is 6.5K*2 + 48K*2 = 22K bytes/BX. All of the total raw data rate is 13.8GB/s.
  - Some additional information of raw data should be included. (Example: Slot number, crate number, board number, gas flow, temperature and humidity…)
  - Trigger and trigger-less options

Parameter	Specification
Noise	<200e
Conversion gain	>15mV/fC
Peaking time (defaul)	100ns
Non lineartity	<1%
Cross talk	<0.3%
Dynamic range	>2000
Power consumption	<5mW/ch

可参考的数据量

- **Pixelated readout TPC is a realistic option to provide at CEPC**
  - **Can deal with high rates (MHz/cm^2)**
  - **Up to 2.6M hits/s per chip (1.4×1.4 cm^2)**

经费预算 – TPC

- **TPC cost estimation**
  - Chamber
  - Endplate
  - Electronics
  - Alignment
  - HV
  - Gas system

TPC COST ESTIMATION (Unit: *10K RMB)						
		Detector concept/ Detector items	Unit	Unit cost (RMB)	Quantity	total cost (RMB)
Number		CEPC				
3.2		**Time Projection Chamber**				18000.00
	3.2.1	**Chamber**				**3600.00**
	3.2.1.1	Fieldcage		1200.00	1	1200.00
	3.2.1.2	Connector		800.00	1	800.00
	3.2.1.3	Barrel		600.00	1	600.00
	3.2.1.4	HV test bef. Assembly		400.00	1	400.00
	3.2.1.5	Support board		600.00	1	600.00
	3.2.2	**Endplate**				**2500.00**
	3.2.2.1	MPGD detector		800.00	1	800.00
	3.2.2.2	Support board		600.00	2	1200.00
	3.2.2.3	Readout bef. Assembly		2.50	200	500.00
	3.2.3	**Electronics**				**10000.00**
	3.2.3.1	FEE ASIC readout		0.012	200000	2400.00
	3.2.3.2	Cables		0.03	50000	1500.00
	3.2.3.3	Optical driver		0.03	50000	1500.00
	3.2.3.4	Optical link, connectors		1.00	500	500.00
	3.2.3.5	DAQ system		0.30	5000	1500.00
	3.2.3.6	Crate and controller		20.00	50	1000.00
	3.2.3.7	Cooling system		1600.00	1	1600.00
	3.2.4	**Alignment and calibration**				**500.00**
	3.2.4.1	Calibration system		500.00	1	500.00
	3.2.5	**HV and Gas system**				**1400.00**
	3.2.5.1	HV and low power		600.000	1	600.00
	3.2.5.2	Gas system		300.00	1	300.00
	3.2.5.3	Slow control system		300.00	1	300.00
	3.2.5.4	Shipping bef. Assembly		200.00	1	200.00

数据参考文献

- 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
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  Di Meglio, Alberto, et al. CERN Quantum Technology Initiative Strategy and Roadmap. No. CERN-OPEN-2021-012. 2021
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Many thanks!