Key issues of TPC for CEPC

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Brief reminder about CEPC

- CEPC operation stages: **10-years Higgs → 2-years Z pole → 1-year W**
- CEPC phy./det. TDR (**preparation**)
  - Physics and detector concept designed under the principle.
  - **Requirements may be with regard to runs of Higgs and Z-pole separately**.
    - Mandatory requirements MUST be met.
    - Auxiliary requirements, if any, are optional.

Chapter 3 of this report outlines that the CEPC is planned to be in operation for 8 months annually, totaling 6,000 hours. This operational schedule is used to calculate the cumulative absorbed doses for magnet coil insulations, as illustrated in Figure 4.2.4.16, considering a 10-year Higgs operation, 2-year Z operation, and 1-year W operation. Figure 4.2.4.17 displays the absorbed doses when an additional 5-year $t\bar{t}$ operation is included. These plots also include the upper limit for absorbed dose in epoxy resin, which is measured at 2×10^7 Gy [11].

CEPC- TDR p116

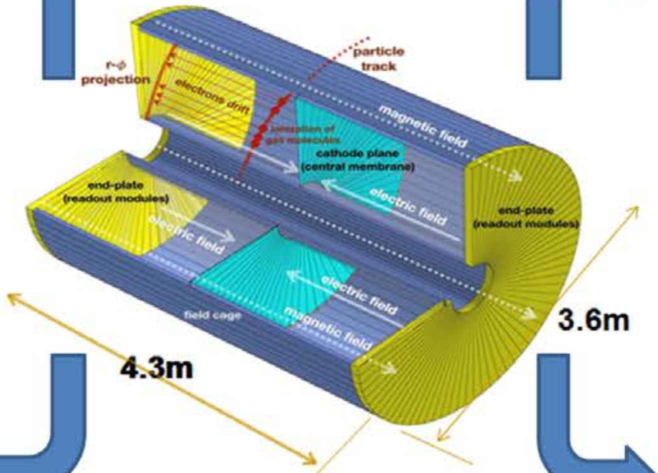
Motivation: TPC requiremetns from e+e- Higgs/EW/Top factories

- TPC can provide hundreds of hits with high spatial resolution compatible, with PFA design (**low X_0**)
  - $\sigma_{1/pt}$ ~10^{-4} $(GeV/c)^{-1}$ with TPC alone and σ_{point}<100μm in rϕ
- **Provide dE/dx and dN/dx with a resolution** <4%
  - Essential for Flavor physics @ Tera Z run

Pad readout TPC
- To meet Higgs physics
- 1mm×6mm of Pad
- TPC module
- TPC prototype with UV laser

TPC track detector for e+e- collider

Pixelated readout TPC
- To meet Z physics
- ~500μm of Pad
- TPC prototype with UV laser track
- dN/dx+dE/dx study



Ion back flow study
- Simulation of Ion Backflow
- Test the UV light created the ions by photoelectric effect
- Experimental study

PID performance Study
- Simulation of the ionization cluster in space
- PID studies of the different readout TPC prototype
- Experimental study

Key issues of TPC technology for e+e- collider

TPC as the main tracker

- **TPC as the main tracker detector to satisfy the physics requirements :**
  - **For Higgs run,** W and top running, **no problem** for all TPC readout technologies.
    - Central Tracking **is entrusted to a pad readout TPC detector**.
  - **For high luminosity (2×10^{36}) Z pole run**:
    - Pixelated readout TPC is a good option at **high luminosity** on the circular e+e- collider.
    - The gating will not be possible, so we need an ion back flow suppression without gating R&D (double or triple mesh/mutil-Mesh, graphene membrane...)
    - Some **intense R&D program has to be addressed**.

TPC key parameters for Higgs run

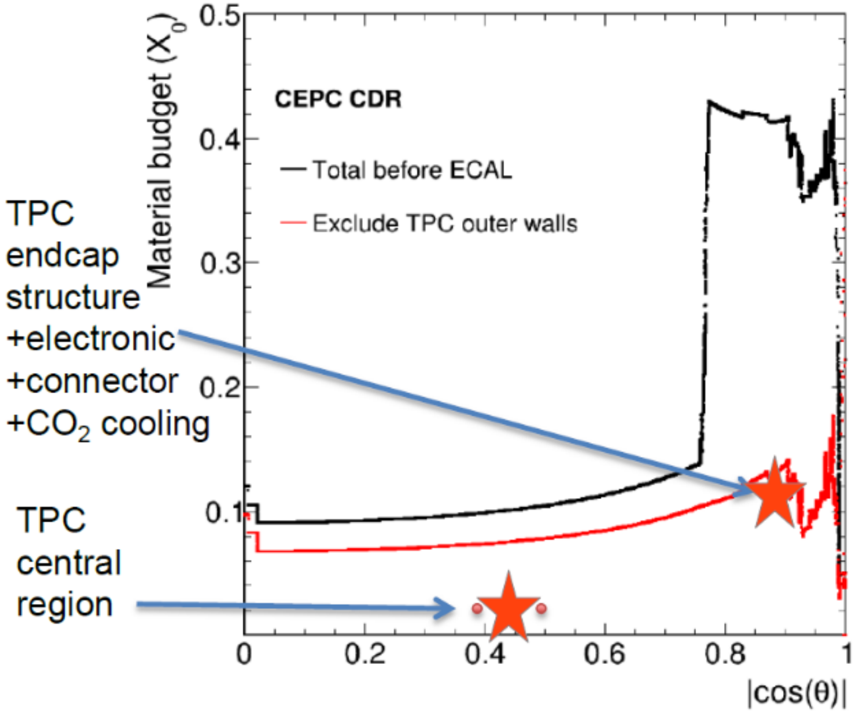
Parameters			
B-field	3.0T without any E×B effect		
Geometrical parameters	r_{in}	r_{out}	z
	0.6m	1.8m	2.5m
Solid angle coverage	Up to cosθ ≃ 0.96		
TPC material budget	≃ 0.05 X_0 including outer fieldcage in r		
	< 0.25 X_0 for readout endcaps in z		
Number of pads	≃ 10^6/1000 per endcap		
Pad pitch/ NO. of Padrows layers	≃ 1×6 mm^2 / 200 points per track in rφ		
σ_{point} in rφ	≃ 60 μm for zero drift, ≤ 100 μm overall		
σ_{point} in rz	≃ 0.4 – 1.4 mm (for zero – full drift)		
2-hit separation in rφ	≃ 2 mm		
dE/dx resolution	≤ 4 % (Pad readout), ≤ 3 % (Pixelated readout)		
Momentum resolution at B = 3.0 T	$\delta(1/p_t) \simeq 1 \times 10^{-4}$/GeV/c (TPC only)		

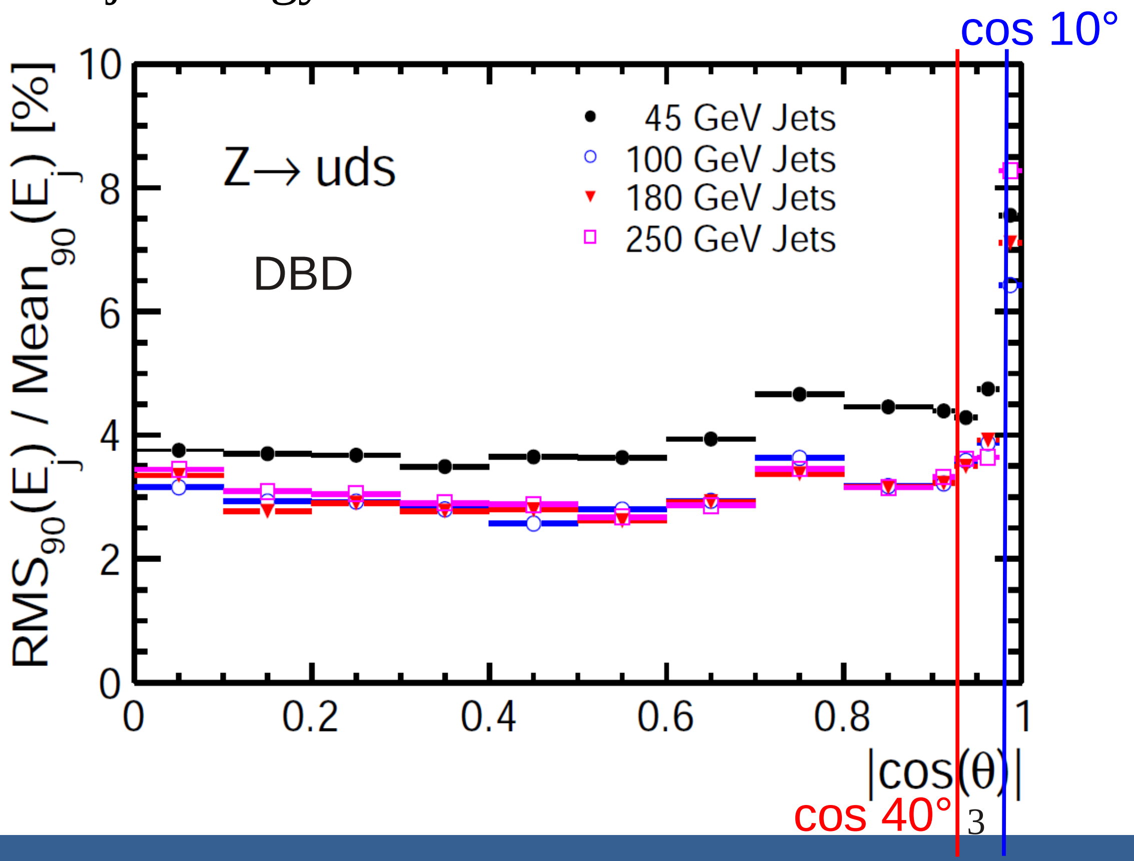
Material Budget – TPC – Very light

- **TPC as the main tracker detector**
  - A low material budget is a strong argument for a TPC
    - $\leq 5\%\ X_0$ in the barrel region
    - $\leq 25\%\ X_0$ in the endcap region
  - Increased material in endcap has no impact on jet energy resolution

	45 GeV	100 GeV	250 GeV
15%X$_0$	0.28±0.01	0.32±0.01	0.47±0.02
30%X$_0$	0.30±0.01	0.31±0.01	0.47±0.02
45%X$_0$	0.30±0.01	0.32±0.01	0.52±0.02
60%X$_0$	0.32±0.01	0.33±0.01	

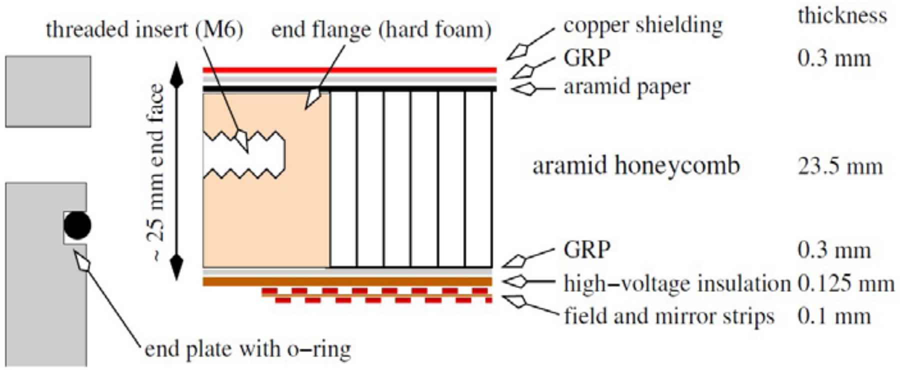
TPC – PRC2010 report

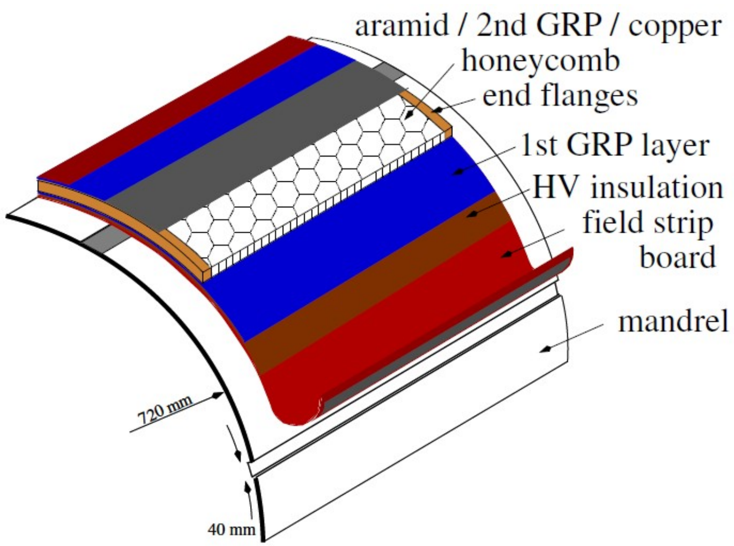


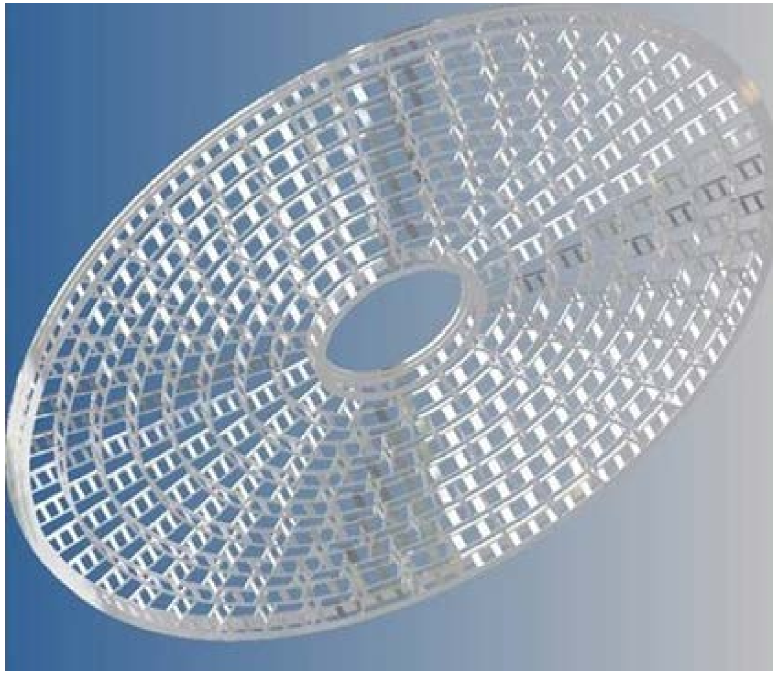


Material Budget – TPC – Validation

- Barrel of the material budget
  - Material budget of **1.2%X_0** was reached
  - Field homogeneity: $10^{-4} < \Delta E/E < 10^{-3}$
  - Operation gas (**negligible**): 1.2kg/m^3
- Endcap of the material budget
  - Readout plane, electronics, detector: <**5%X_0**
  - Cooling: <**2%X_0**
  - Power cables: <**10%X_0**

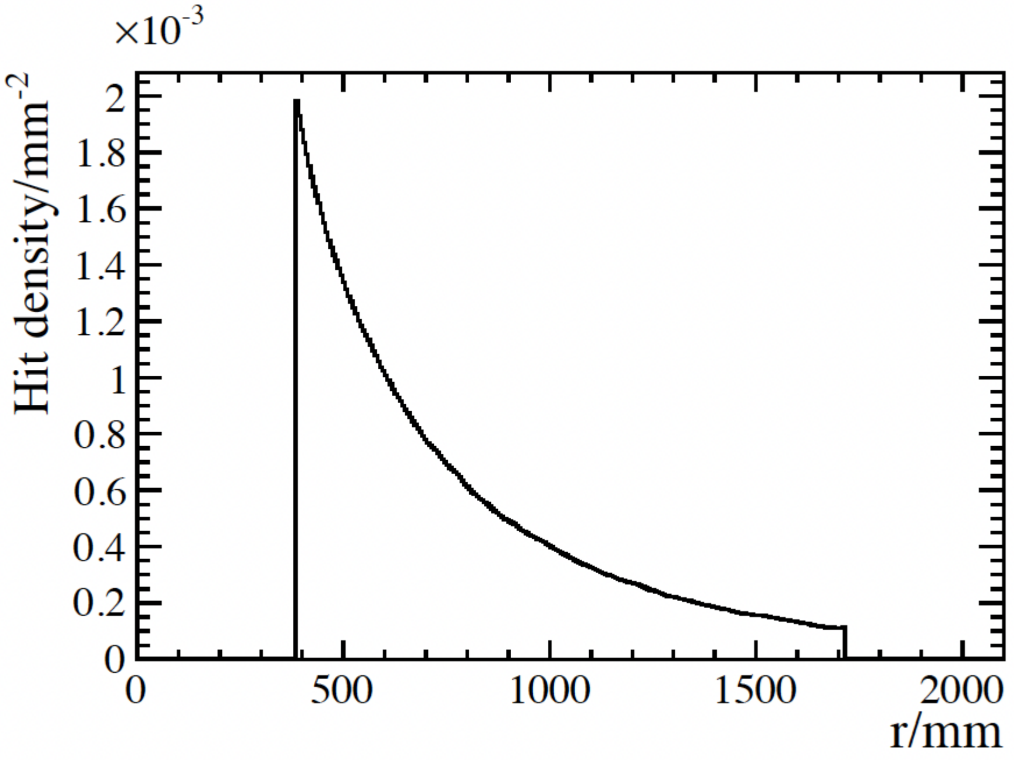






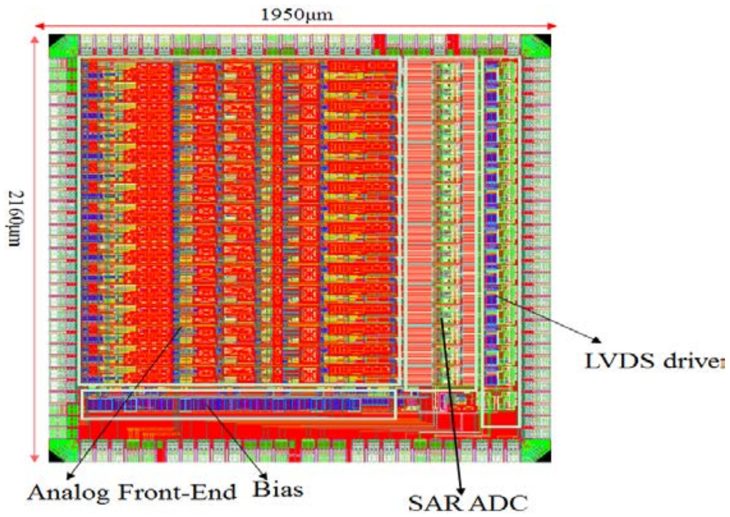
Occupancy – TPC - Safe

- **TPC occupancy**
  - Low voxel occupancy : 1E-5 to 1E-6
  - At 2 E36 with Physics event only, even bunch distribution.
  - Pad readout (1mm×6mm)
    - inner most occupancy 1E-4
  - Pixelated readout (55um×55um)
    - much LOWER inner most occupancy ~1E-6
  - Pixelated readout can easily handle a high hits rate at Z
    - The test beam showed GridPix TPC prototype can handle up to 2.6M hits/s per chip



Power Consumption – TPC - Validation

- **Power consumption**
  - Pad readout TPC@1mm×6mm@IHEP
  - Total channels: **10^6**
  - Total power: <12 kW
    - 48mW/cm^2
    - WASA ASIC chip: 3.5mW/ch@40 MS/s

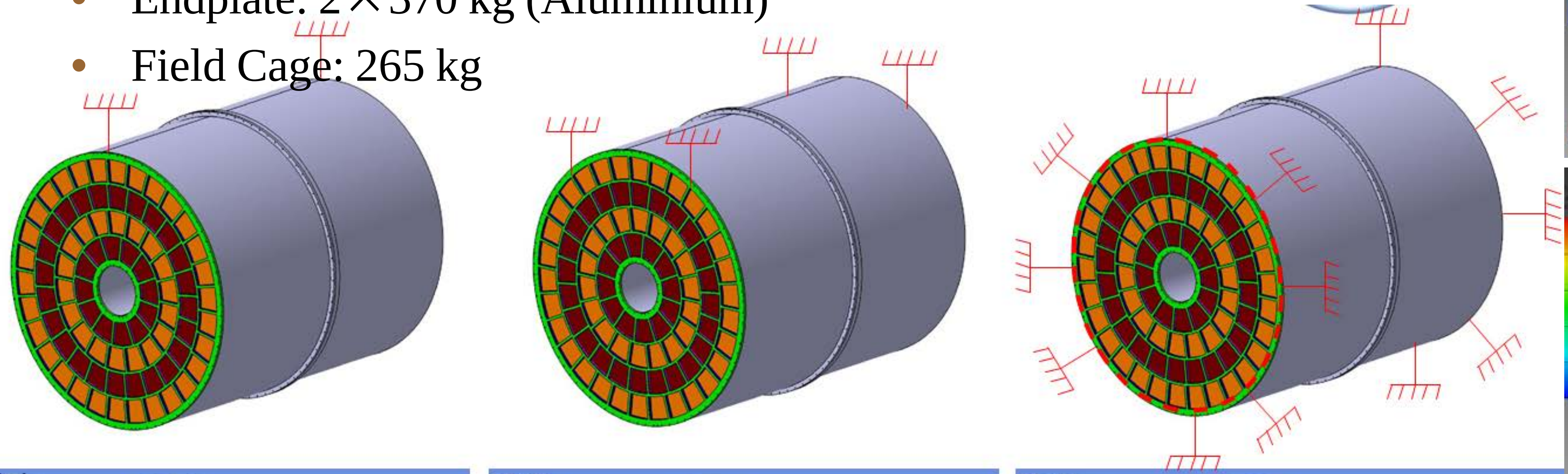


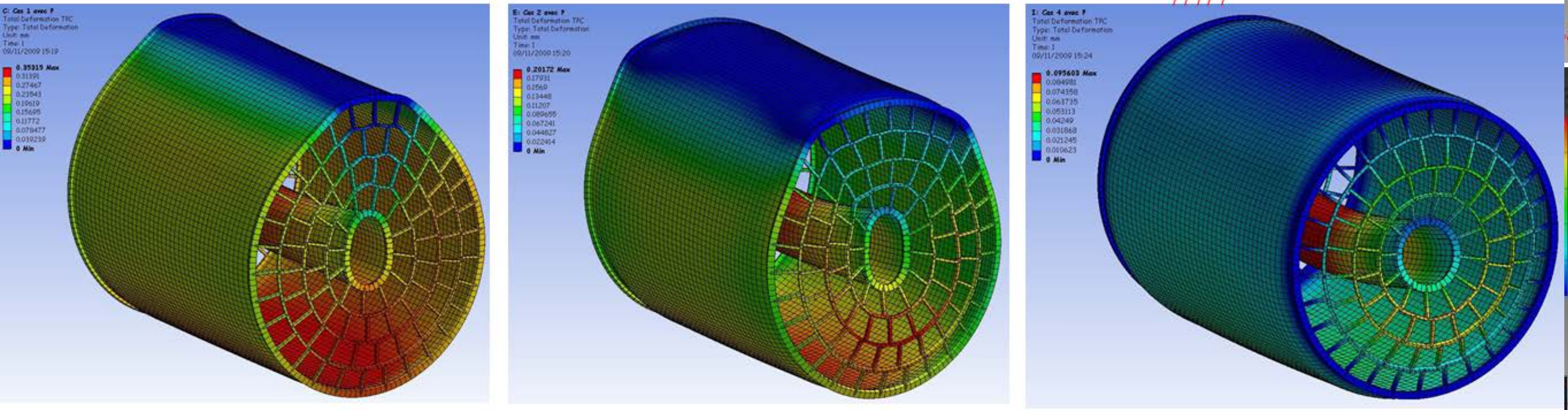
	AGET	PASA+ALTRO	Super-ALTRO	SAMPA
TPC	T2K	ALICE	ILC	ALICE upgrade
Pad尺寸	6.9x9.7 mm^2	4x7.5 mm^2	1x6 mm^2	4x7.5 mm^2
通道数	1.25 x 10^5	5.7x 10^5	1-2 x 10^6	5.7 x 10^5
读出结构	MicroMegas	MWPC	GEM/MicroMegas	GEM
增益	0.2-17 mV/fC	12 mV/fC	12-27 mV/fC	20/30 mV/fC
成型方式	$CR\text{-}(RC)^2$	$CR\text{-}(RC)^4$	$CR\text{-}(RC)^4$	$CR\text{-}(RC)^4$
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

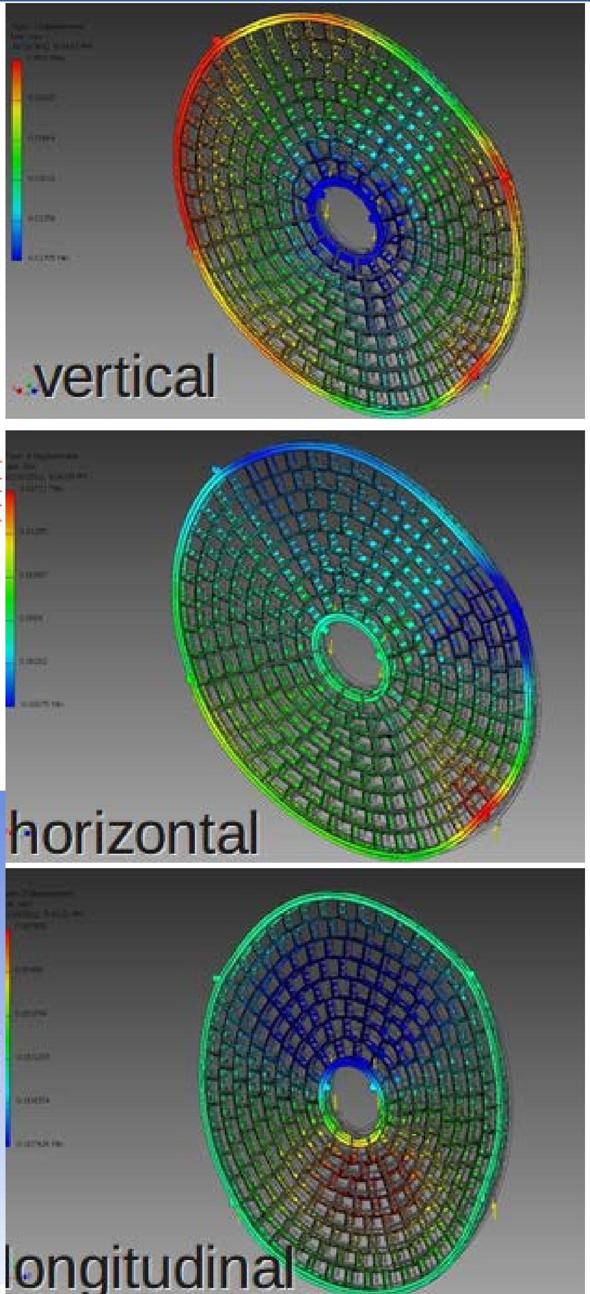
Various Possibilities of Mounting TPC

- **TPC Material and Weight**
  - PCB: 2×530 kg (on basis of 7kg/module, FR4)
  - Endplate: 2×370 kg (Aluminium)
  - Field Cage: 265 kg

Maximum deflection of the model:
~0.00867mm/100 N







Cost – 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

- **TPC as the main track detector for CEPC**
  - **Material budget of endplate/chamber √**
  - **Occupancy √**
  - **Optimization of pad size √**
  - **Channels and power consumption √**
  - **Cost estimation √**
  - **Ions affect and distortion √ (need R&D for Z pole)**
  - **Improved dE/dx+dN/dx √ (need R&D Z pole)**

Many thanks!