TPC cost estimation and optimization

Huirong Qi

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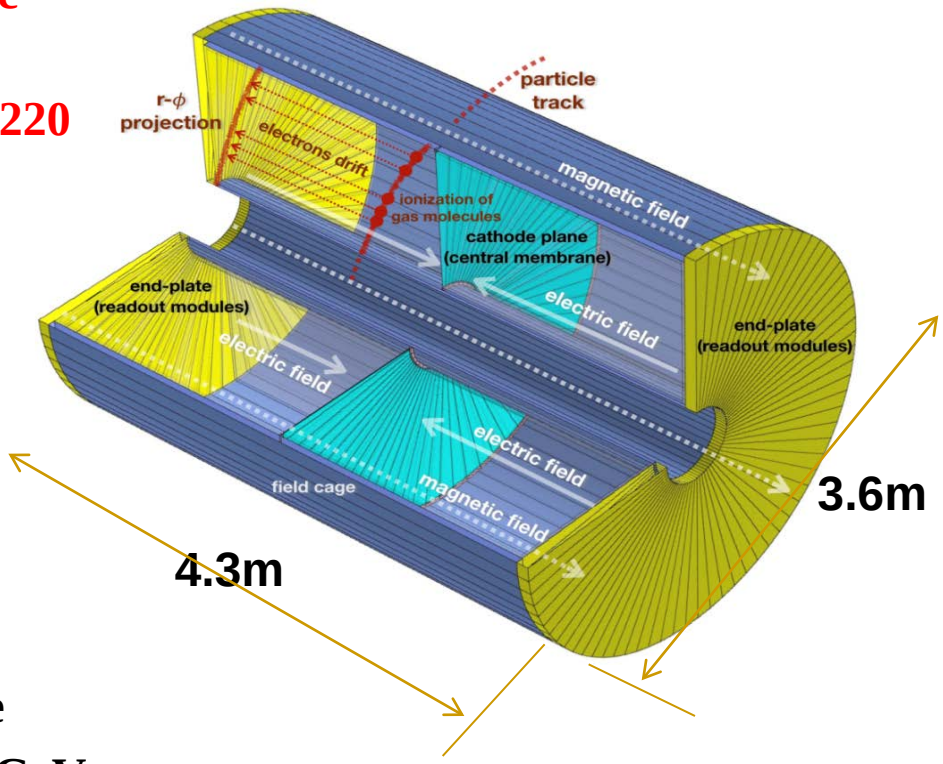
Overview: physics requirements

TPC detector concept:

- **Under 2-3 Tesla magnetic field (Momentum resolution: ~10^{-4}/GeV/c with TPC standalone)**
- **Large number of 3D space points(~220 along the diameter)**
- **dE/dx resolution: <5%**
- **~100 μm position resolution in rφ**
  - **~60μm for zero drift, <100μm overall**
  - **Systematics precision (<20μm internal)**
- **TPC material budget**
  - **<1X_0 including outer field cage**
- **Tracker efficiency: >97% for pT>1GeV**
- **2-hit resolution in rφ : ~2mm**
- **Module design: ~200mm×170mm**
- **Minimizes dead space between the modules: 1-2mm**



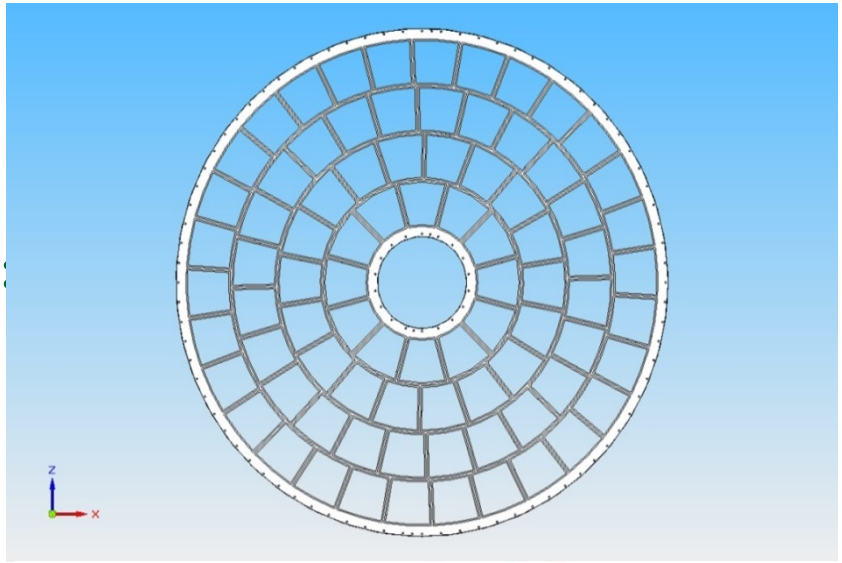
TPC detector concept

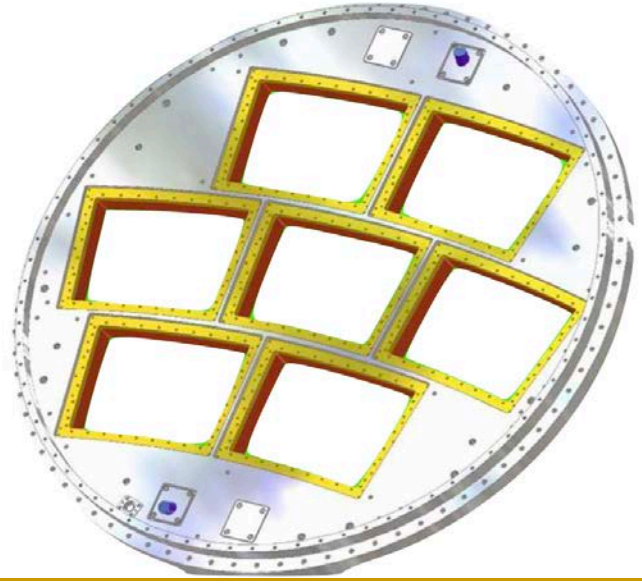
Rules for TPC costing Preliminary

- Same dimensions as the ILD TPC
- Inner radius 395 mm (active area)
- Outer radius 1.739 mm (active area)
- 1×6 mm^2 pad (default pad size)
- 224 pad rows (default pad size)
- T2K gas (Ar/CF4/iC4H10=95/3/2)
- Vdrift = 80 μm/ns
- Voxel size (3D space bucket):
  - Pad_size × t_sample · v_drift
  - about 1 mm × 6 mm × 2 mm

Pad TPC for collider

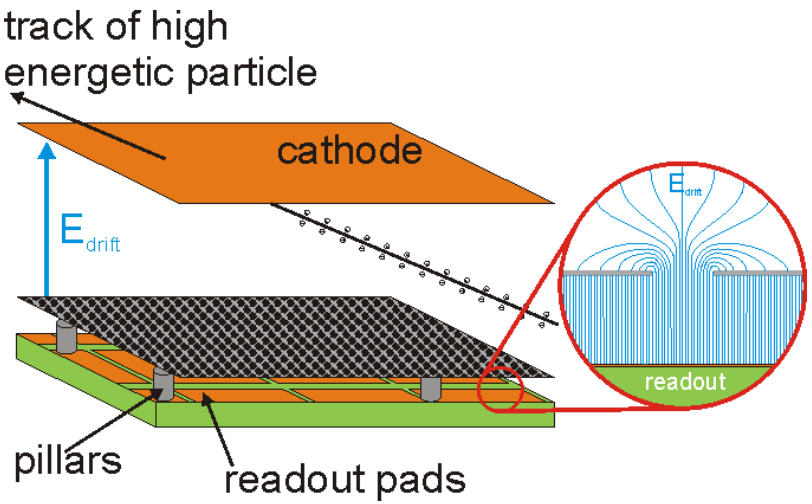
- Active area: 2×10m^2
- One option for endplate readout:
  - GEM or Micromegas
  - 1×6 mm^2 pads
  - 10^6 Pads
  - 84 modules
  - Module size: 200×170mm^2
  - Readout: Super ALTRO
  - CO_2 cooling





TPC detector endplate concept

Pixel TPC for collider



For Collider @cost:
But to readout the TPC with GridPixes:
→100-120 chips/module
240 modules/endcap (10 m^2)
→50k-60k GridPixes
→ 10^9 pixel pads

Benefits of Pixel readout:

- **Lower occupancy**

→ 300 k Hits/s at small radii.

→ This gives < 12 single pixels hit/s.

→ With a read out speed of 0.1 msec (that matches a 10 kHz Z rate)

→ the occupancy is less than 0.0012

- Improved dE/dx

→ primary e- counting

  - Smaller pads/pixels could result in better resolution!
  - Gain <2000
  - Low IBF*Gain<2
  - CO_2 cooling

Pixel option cost estimation

- The total cost of a pad or a pixel read out is pretty similar; all readout options need cooling and electronics and that drives the read out cost.
- For the prototype, we know the costs, but they will go down substantially because of prices going down for large numbers. E.g. for 1 module of 100 chips we need 1 wafer 3000 euro plus post processing 3000 euro
- All the costing done for ILD is more realistic for TPC concept.

COST estimation

Total: 180 Millions RMB

TPC COST ESTIMATION(unit: *10K RMB)

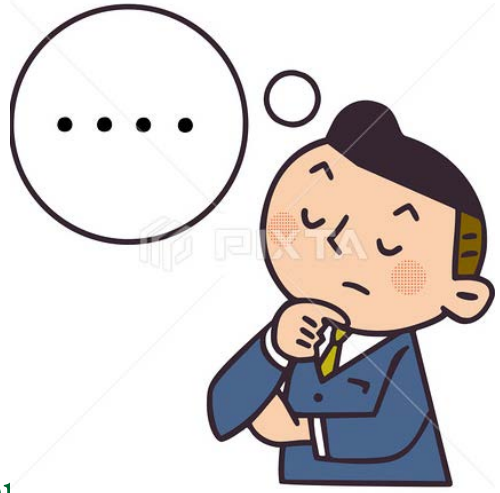
ITEM	DEVICE ITEM	TYPE	UNIT	Quantity	Prive/	Total
3.1	TPC detector (TPC)					18000.00
3.1.1	Chamber					3600.00
3.1.1.1	Fieldcage		set	1	1200.00	1200.00
3.1.1.2	Connector		set	1	800.00	800.00
3.1.1.3	Barrel		set	1	1000.00	1000.00
3.1.1.4	Support device		set	1	600.00	600.00
3.1.2	Readout					2500.00
3.1.2.1	MPGD detector		set	1	800.00	800.00
3.1.2.2	Support board		set	2	600.00	1200.00
3.1.2.3	Readout board		board	200	2.50	500.00
3.1.3	Electronics					10000.00
3.1.3.1	FEE ASIC readout		channel	1200000	0.002	2400.00
3.1.3.2	Cables		set	50000	0.03	1500.00
3.1.3.3	Optical driver		set	50000	0.03	1500.00
3.1.3.4	Optical link, connectors		set	500	1.00	500.00
3.1.3.5	DAQ		set	5000	0.30	1500.00
3.1.3.6	Crate and controller		set	50	20.00	1000.00
3.1.3.7	Cooling sytem		set	1	1600.00	1600.00
3.1.4	Calibration					500.00
3.1.4.1	Calibration system		set	1	500.00	500.00
3.1.5	HV and Gas system					1400.00
3.1.5.1	HV and low power		set	1	800.00	800.00
3.1.5.2	Gas system		set	1	300.00	300.00
3.1.5.3	Monitor system		set	1	300.00	300.00

2019 cost (Micromegas option)

ILD smaller: 184 Millions RMB
Size: reduce 15%

Colonne1	Colonr	Colonne2	Colonne4	Colonr	Detector concept / detector items	Unit	Unit cost (€)	Quantity	total m&s	Home/Industry	associated unit labor (FTE.year)	labor cost
WBS Number					ILD							
	1.2				Time projection Chamber				23, 638, 740. 00			
		1.2.1			Field cages				5,800,000.00			
			1.2.1.1		inner fieldcage		860000	1	860,000.00			
			1.2.1.2		outer fieldcage		4300000	1	4,300,000.00			
			1.2.1.3		central membrane		300000	1	300,000.00			
			1.2.1.4		hanging and damping				30,000.00			
			1.2.1.5		HV test bef. Assembly				10,000.00			
			1.2.1.6		shipping				300,000.00			
		1.2.2			Endplates			2	540,000.00			
			1.2.2.1		base material (Al)		10, 000. 00	2	20,000.00			
			1.2.2.2		machining		40, 000. 00	2	80,000.00			
			1.2.2.3		Fixtures		10, 000. 00	2	20,000.00			
			1.2.2.4		Module jigs		500. 00	120	60,000.00			
			1.2.2.5		shipping				300,000.00			
			1.2.2.6		assembly				60,000.00			
		1.2.3			Modules (20 spares)			140	2,042,800.00			
			1.2.3.1		back-frames	frame	1, 000. 00	140	140,000.00			
			1.2.3.2		PCBs	PCB	2, 000. 00	140	280,000.00			
			1.2.3.3		mesh and DLC	detector	4, 000. 00	140	560,000.00			
			1.2.3.4		connectors	connector	45. 00	13440	604,800.00			
			1.2.3.5		storage boxes	box	200. 00	140	28,000.00			
			1.2.3.6		shipping		70, 000. 00		70,000.00			
			1.2.3.7		Mounting and test				360,000.00			
		1.2.4			Ancillaries				2,256,400.00			
			1.2.4.1		CO2 compressor	compressor	65, 000. 00	14	910,000.00			
			1.2.4.2		CO2 comp. Shipping	compressor	7, 000. 00	14	98,000.00			
			1.2.4.3		Gas mixer				400,000.00			
			1.2.4.4		Gas analyser				100,000.00			
			1.2.4.5		laser system				540,000.00			
			1.2.4.6		HV power supplies	supply	6, 000. 00	12	72,000.00			
			1.2.4.7		HV racks	rack	5, 000. 00	2	10,000.00			
			1.2.4.8		LV power supplies	8-channel supply	7900	16	126,400.00			
		1.2.5			Cables and pipes				49,540.00			
			1.2.5.1		HV cable (60m) x120	60m HV cable	130. 00	120	15,600.00			
			1.2.5.2		LV cable	cable	25. 00	120	3,000.00			

Idea: intermediate solution between pads and pixels for CEPC at Z



- Clusters contain the primary information of the ionisation
- Can we find a solution to resolve clusters?
- Some R&D for pixel TPC:
  - What is the optimal pad size to
    - improve double hit and double track resolution
    - do cluster counting for improved dE/dx?

    → Pixel size:(200μm or large)

    → significant reduce cost
- Almost without IBF (Gain< 2000)
- Micromegas + ASIC Chips (Our option)
- GEMs + ASIC Chips

  → Some R&D at DESY