Some considerations and plan for Pixel TPC at Tera Z

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December, 30, 2019

- In this talk presented issues with a TPC running at Tera Z
  - Physics requirements
  - Ion Back Flow
  - Rate capabilities
  - Background at IP
  - Cost and consumption
  - Some update plan in 2020

Physics requirements

- TPC limitations for Z
  - Ions back flow in chamber
  - Calibration and alignment
  - Low power consumption FEE ASIC chip

	ALICE TPC	CEPC TPC
Maximum readout rate	>50kHz@pp	w.o BG?
Gating to reduce ions	No Gating	No Gating
Continuous readout	No trigger	Trigger?
IBF control	Build-in	Build-in
IBF*Gain	<10	<5
Calibration system	Laser	NEED

Compare with ALICE TPC and CEPC TPC

CEPC CDR

Lumi.	Higgs	W	Z	Z(2T)
$\times 10^{34}$	2.93	11.5	16.6	32.1

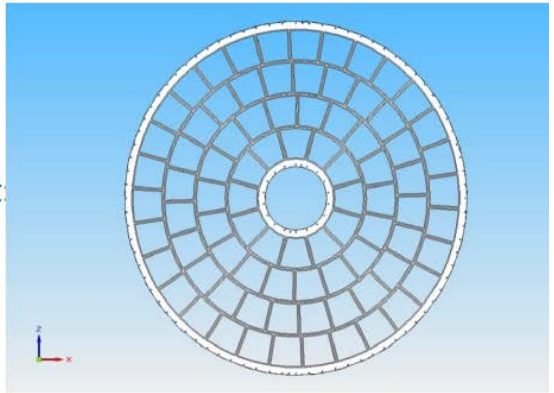
Luminosities exceeded those in the preCDR

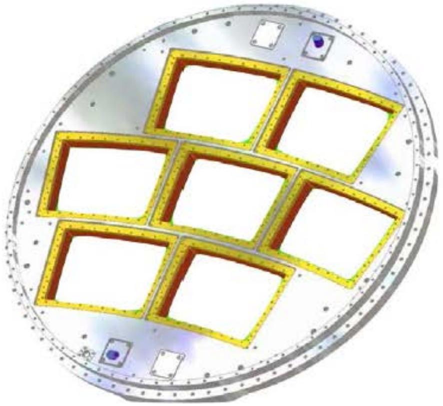
- double ring baseline design (30MW/beam)
- switchable between H and Z/W w/o hardware change (magnet switch)
- use half SRF for Z and W
- can be optimized for Z with 2T detector

Pad TPC and Pixel TPC

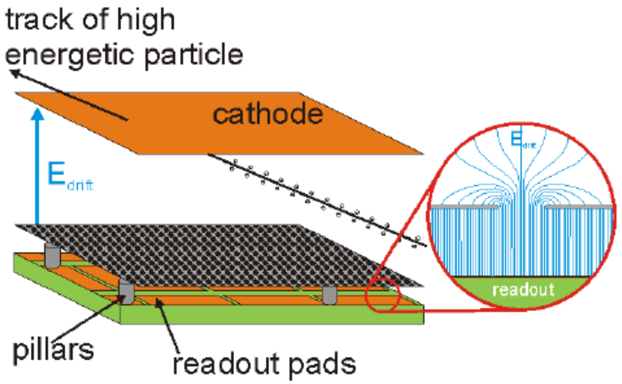
Pad TPC for collider

- Active area: 2×10m^2
- One option for endplate readout:
  - GEM or Micromegas
  - 1×6 mm² pads
  - 10^6 Pads
  - 84 modules
  - Module size: 200×170mm^2
  - Readout: Super ALTRO
  - CO_2 cooling





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

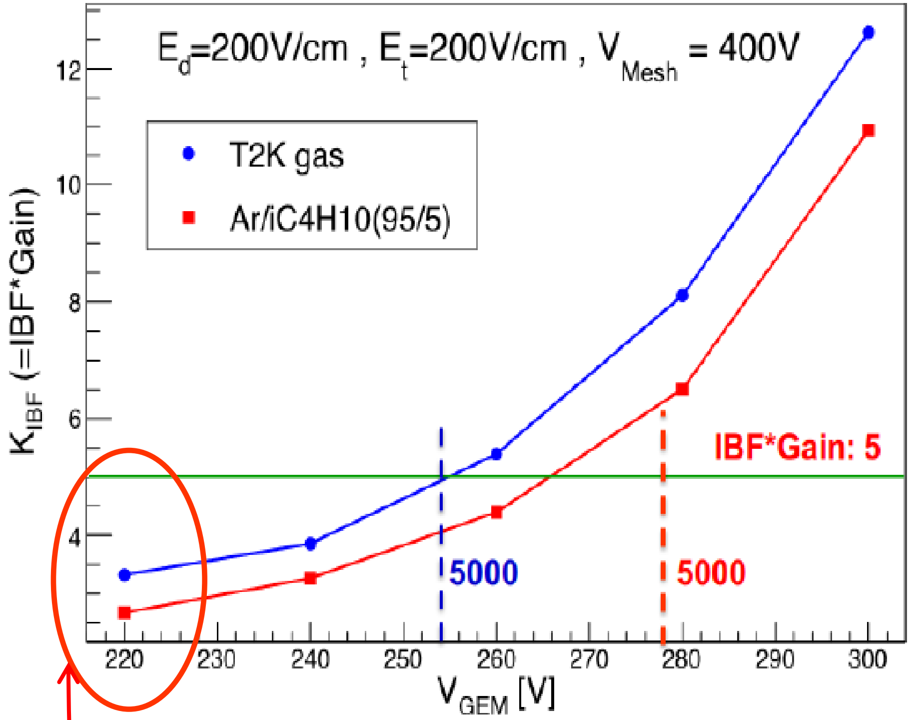
CEPC Pixel TPC – **Ions backflow**

- Situation for a pixel TPC
  - Large potential in terms of rate capabilities
  - Pattern recognition high granularity works in high Z rate
  - Question: what is the IBF for our GridPix?
    - **O(0.1%) It will be measured with IHEP and Nikehf's collaborations.**

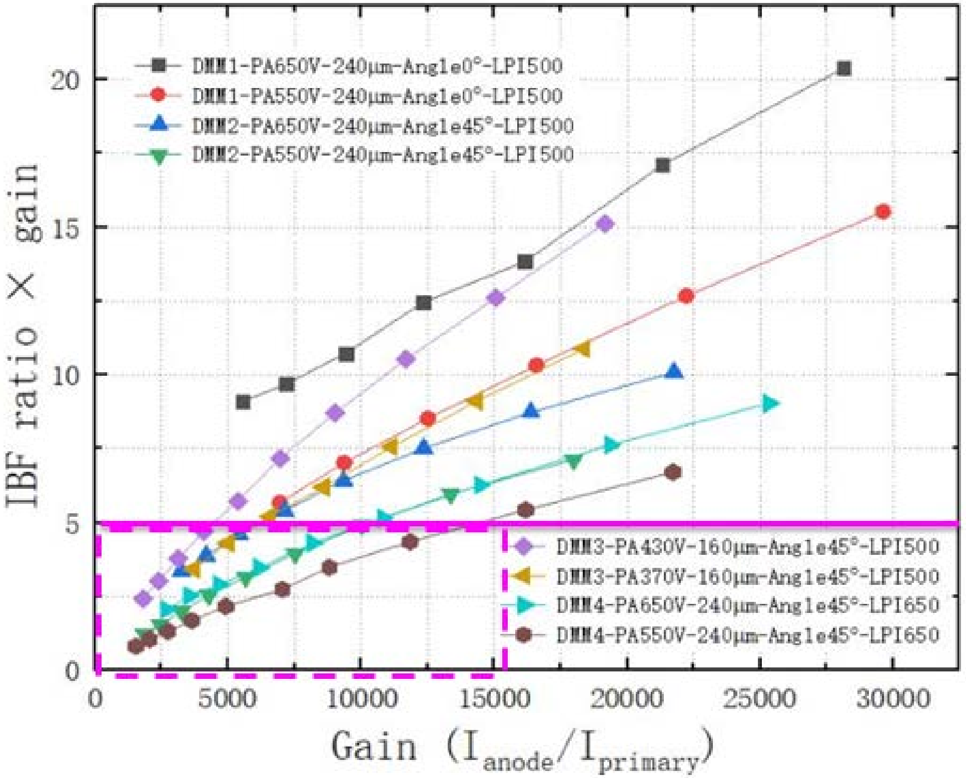
- Can TPC apply in Z collisions?
  - High(est) luminosity CEPC L = 32-50 (17-32) 10^{34} $cm^{-2}s^{-1}$ at 2 T.
    - CEPC Ring length 100 km with 12 000 bunches and a hadronic Z rate of 10-15 (5-10) k Hz (cross section 32 nb).
    - Beam structure rather continuous 14 ns spacing.
    - Note that this Luminosity gives about 60-120 (30-60) G Zs per running year
  - Time between Z interactions 120-60 (200-100) μs
  - TPC drift time takes -30 μs
  - So events are separated in the TPC
  - Need IBF suppression and IBF*Gain <2

TPC module R&D – **Ions backflow**

Micronegas + GEM detector module@IHEP



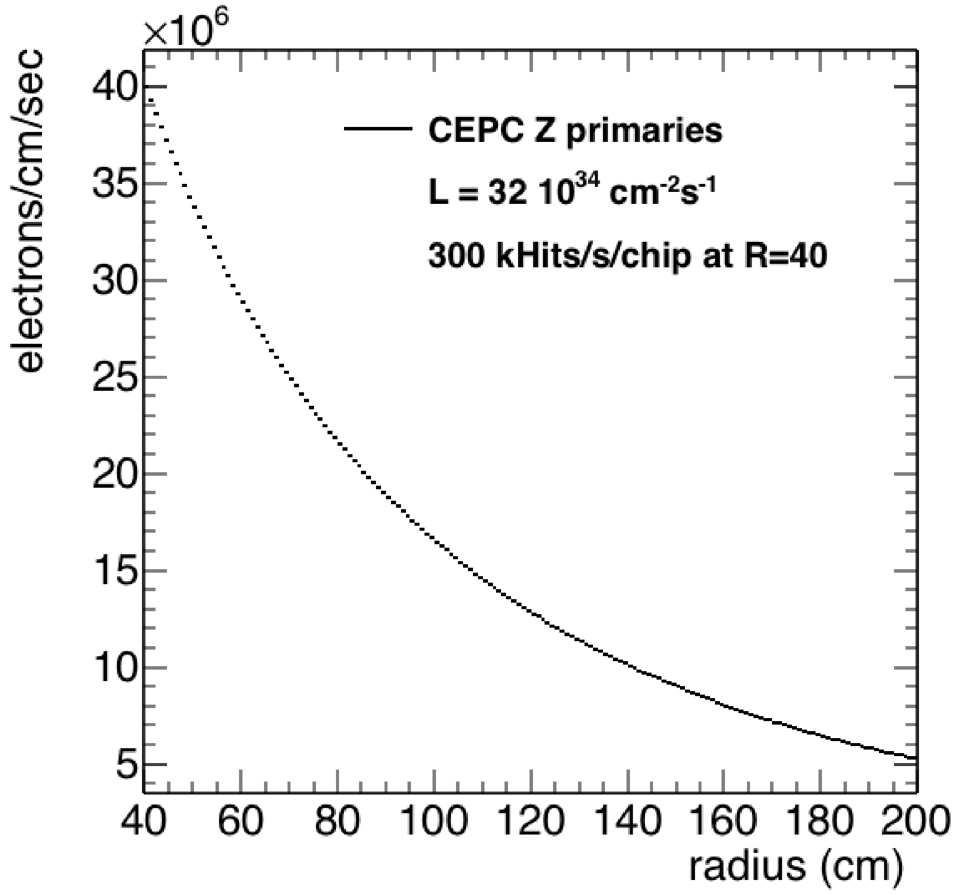
IBF of double mesh MM @USTC/Jianbei Liu



- IBF×Gain has the limitation ratio from the detector R&D at high gain.
- How to do it next ? Any new ideas? (Lower gain and no IBF)

CEPC Pixel TPC rates

- Rates primary electrons in a Pixel TPC (back of the envelop)



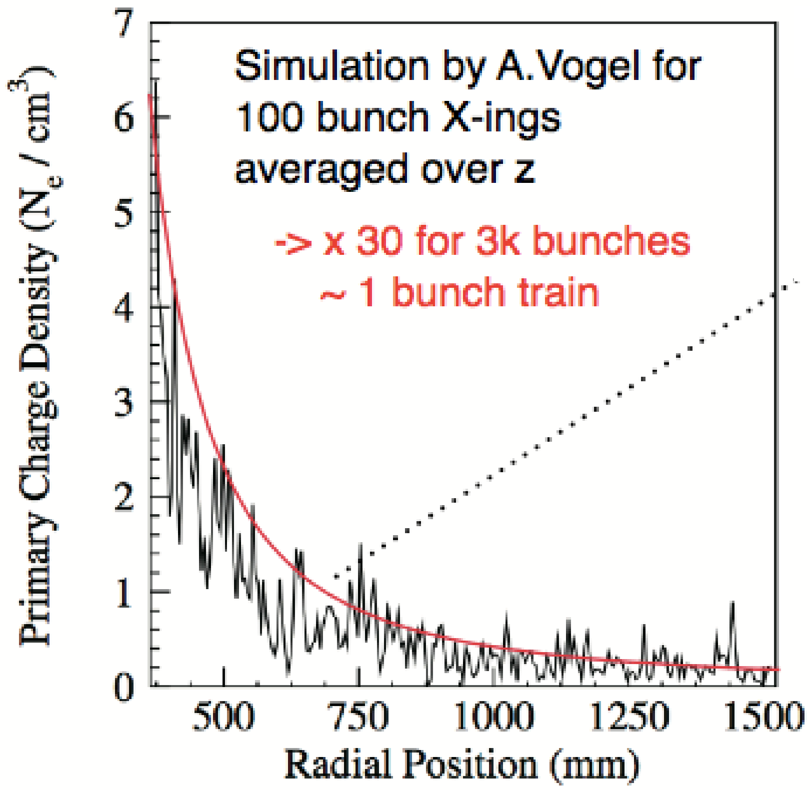
- Using a simulation program the primary Z hit rate in the pixel TPC is calculated as a function of the radius.
- The rate amount to 300 k hits /s at a radius of 40 cm.
- This is a rate the current quad and read out can easily handle.
- The test beam showed we can handle up to 2.6M hits/s per chip (1.42x1.42 cm^2). **So about a factor 10 higher than what is needed.**
- Occupancy rate 40/s (256*256 pixels)
  - With 0.1 ms read out< 0.004 (10kHz)

CEPC Pixel TPC - **Rate capabilities**

- High rate capabilities of the GidPix pixel chips
  - Test beam was 5 kHz electrons for a quad module
  - Link speed 80 Mbps per chip (256x256x 55 x 55 μm^2)
  - Test beam in 2018: 1.3M hits/s per chip could be read out
  - Test beam in 2019: Doubled to 2.6M hits/s per 1.42x1.42 cm^2.

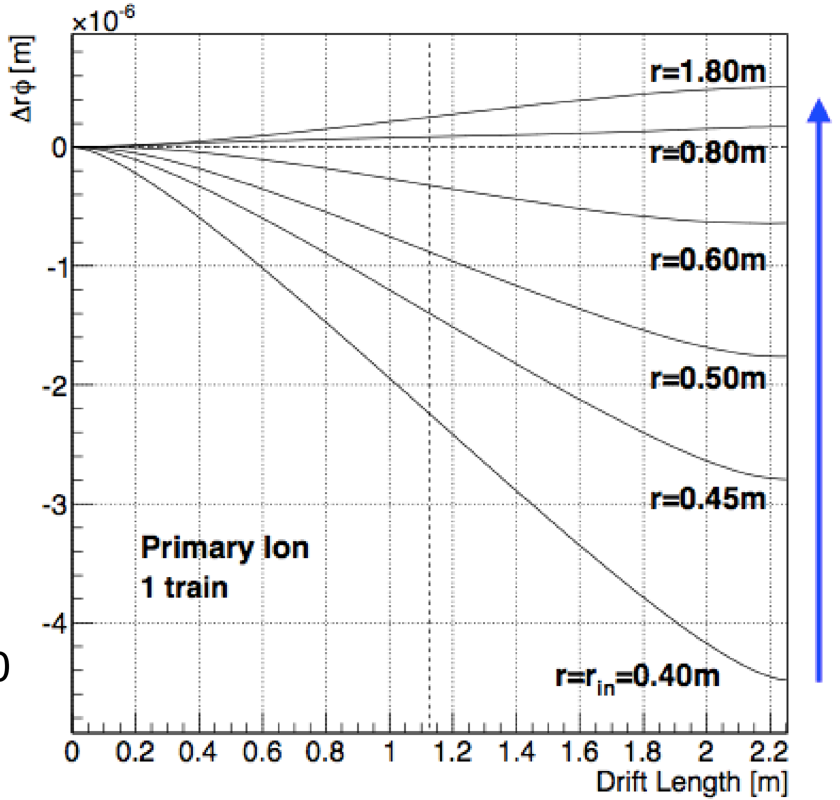
- **Rate estimates** for primary electrons and charge and distortions from primary ions due to Zs (back of the endplate)
  - Assume that the ions stay 0-300 ms before reaching the mid plane of the TPC. With a rate of 10-15 kHz one will accumulate 3000 - 4500 Zs;
  - This gives 30 tracks producing 10^4 primary electrons and ions. TPC volume:
  - Inner radius 40 cm; outer 180 cm; 400 cm length;
  - Volume 3.8 10^7 cm^3. Charge density = $9\text{-}13\times10^8/3.8\times10^7$ cm^3 = 23-34 e/cm^3. This is smaller than the charge at the ILC for 3000 bunches from beam-beam background (next slide).

ILC beam-beam primary ions in TPC



Fit by D.Arai

$$\bar{\rho}_r(r) = 1.6 \times \frac{1}{4(r-0.2)^2} \times 30 \times 10^{-13} \quad [\mathrm{C/m^3}]$$



For a primary charge distribution (x 30) are less than 5μm

Studies from Keisuke Fuji https://agenda.linearcollider.org/event/5504/contributions/24543/attachments/20144/31818/PositiveIonEffects-kf.pdf)

CEPC backgrounds Pixel TPC

- Important to estimate the charge in the TPC as it causes distortions.
  - Physics events like Zs
  - Other backgrounds γγ background and incoherent pairs from beam-beam interactions that produce hits
- What is the charge of the other backgrounds in the TPC?
  - At ILC beam-beam effects from primary ions are dominant over the physics interactions.
  - However TLEP and FCCee studies show that e.g. γγ background are very small at the Z. Also the incoherent pair production (backup slides) is several orders smaller than at the ILC.
  - **As Adrian Vogel (DESY-thesis-08-036) in his thesis showed the detector -machine design is important to reduce the number of back scattered photons.** See plot below.

DESY-thesis-08-036

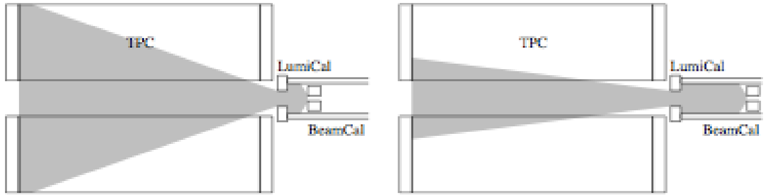
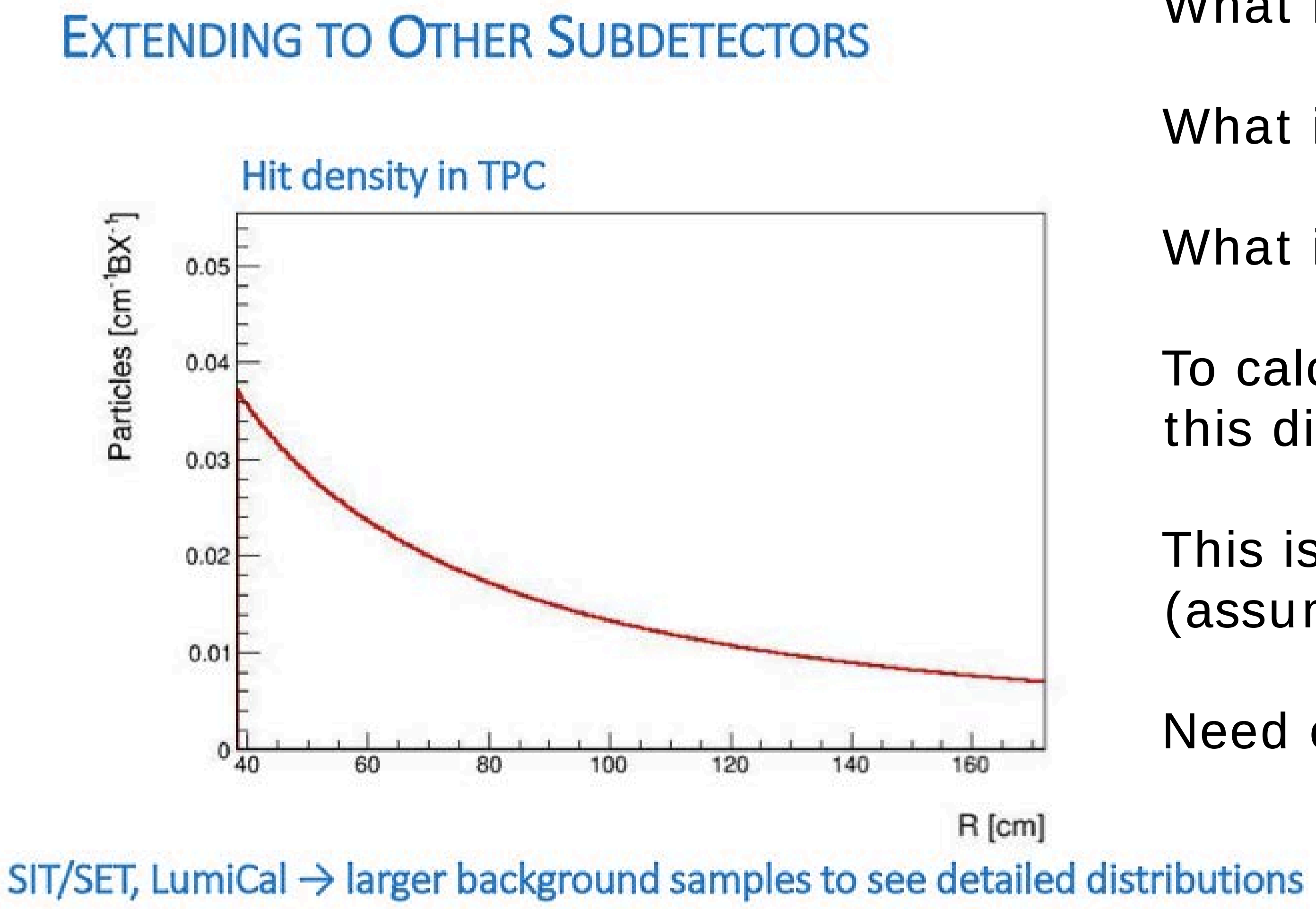


Figure 7.32: A larger distance between LumiCal and BeamCal reduces the backscattering of photons into the TPC.

Hongbo
CEPC
Oxford

CEPC Pixel TPC



What is the energy (Z pole, 91 GeV) ?

What is the type of background?

What is a hit/particle in the TPC?

To calculate the charge (Radius) from this distribution.

This is 8×10^{-5} particles/cm^2/BX (R=40) (assume z TPC 2*220 cm).

Need optimized parameters input.

Cost and Power consumption

Total：184 Millions RMB
2019.11

2019 cost (Micromegas option)

Colonne1	Colonr	Colonne	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			

- 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, E.g. for 1 module of 100 chips that need 1 wafer 3000 euro plus post processing 3000 euro，It will go down substantially because of prices going down for large numbers.
- All the costing done for ILD is more realistic for TPC concept.

Some update plan in 2020

- LCTPC collaboration in January
  - Pixel TPC option for CEPC/FCC circular collider @ one day meeting
    - TPC module: Bean test and measurement
    - Pixel TPC module: IBF study
    - Cooling study of the readout
      - Two phase CO2
    - Cost estimation
- Discussion meeting at IHEP in February
  - Physics simulation (Manqi, Gang…)
  - Invited some professor from TPC R&D
    - USTC, Tsinghua, IMP, Shanghai Jiaotong, Shandong, Peking University (DONE: Call invitation)
  - Summarization from LCTPC discussion
- Discussion and collaboration at CEPC workshop in April
  - Paul, Serguei, Stephan, Roy from Saclay
- TPC module and prototype R&D according to MOST and other Funding


2019


2020
HAPPY NEW YEAR