Status of R&D for Time projection chamber module and prototype for CEPC

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Institute of High Energy Physics, CAS
Tsinghua University

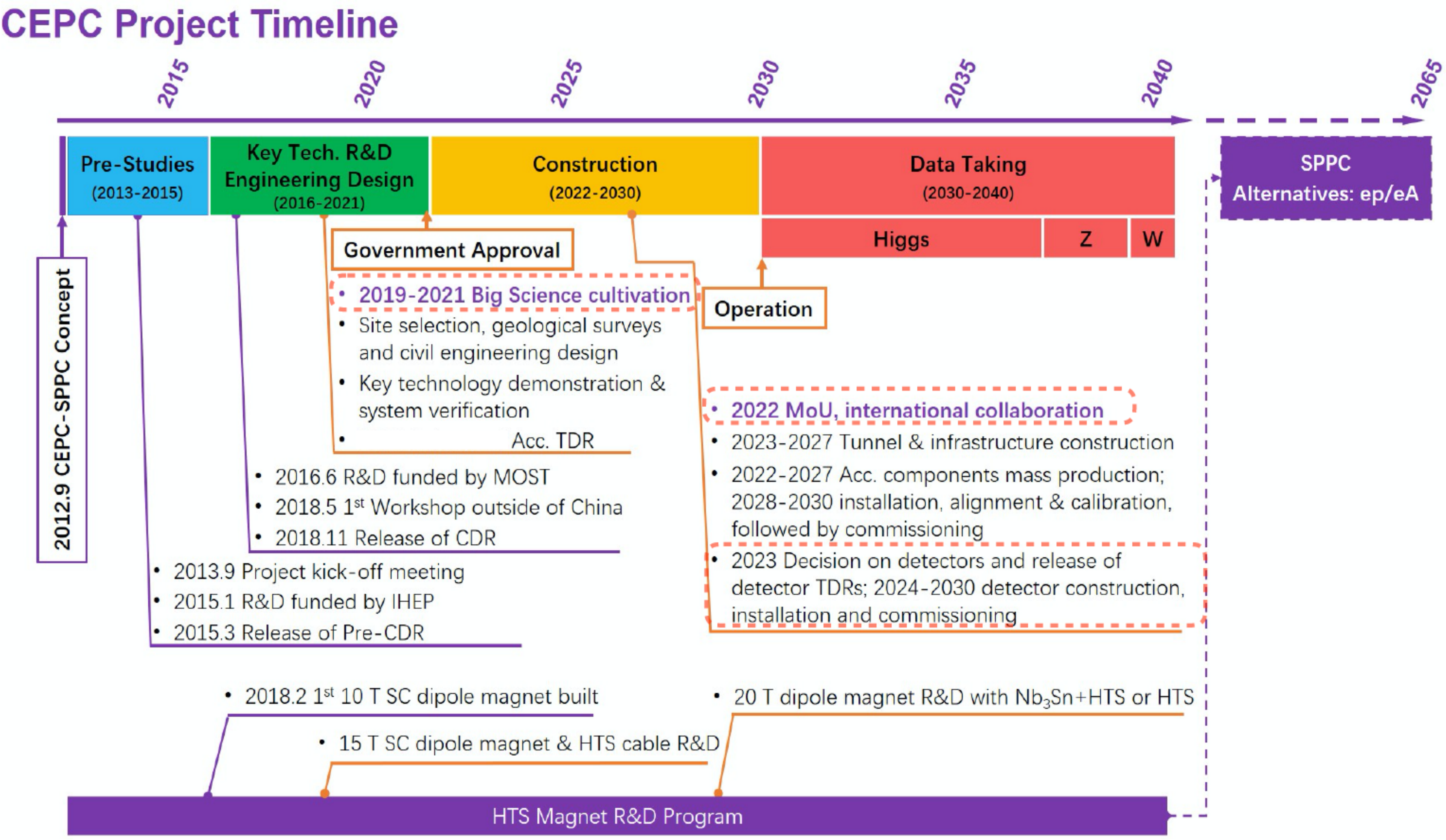
LCTPC Collaboration meeting, DESY, Jan., 13, 2020

Outline

- CEPC project
- Physics requirements
- TPC prototype R&D
- Summary

CEPC project timeline

Xin chou's talk



CEPC size

Forbidden city
3.5km
BEPC, IHEP
240m
2nd road
3rd road
4th road
5th road ring of Beijing
98.5km
百望山
清华大学
香山公园
北京奥林匹克公园
元大都城垣遗址
北京西山国家森林公园
海淀区
将府公园
蓝调薰衣草庄
东城区
红领巾公园
石景山区
北京市
北京西站
古塔公园
北京南站
丰台区
海棠公园
南海子公园
桑园村
G101
S12
G102
S302
G107
S315

CEPC Site Selections

Gao Jie's talk

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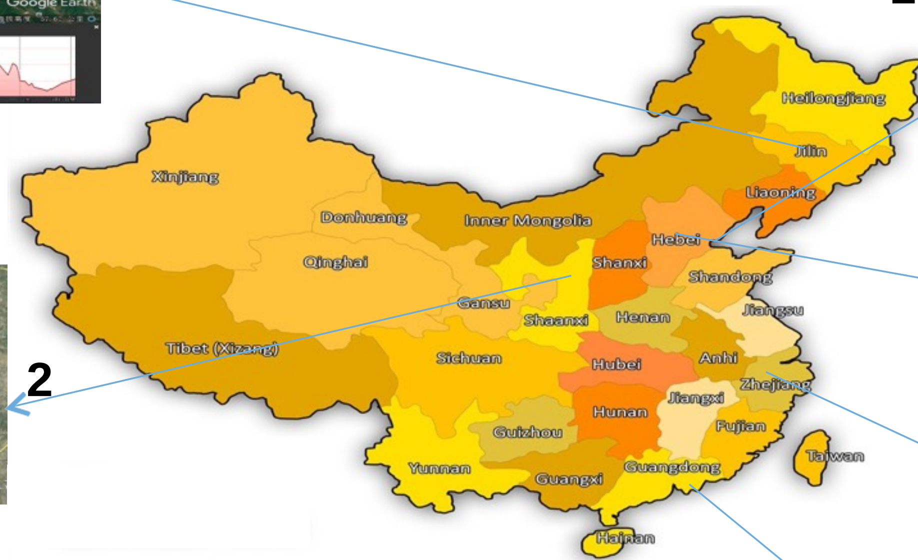
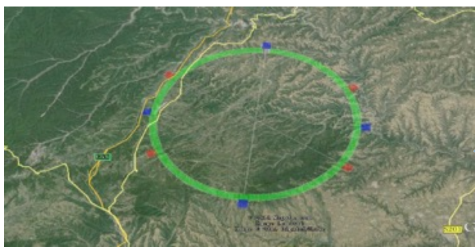


1

4

2



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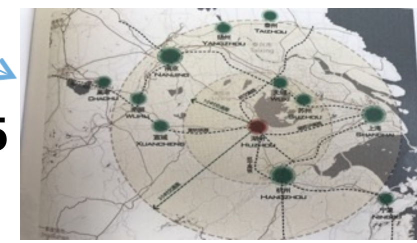
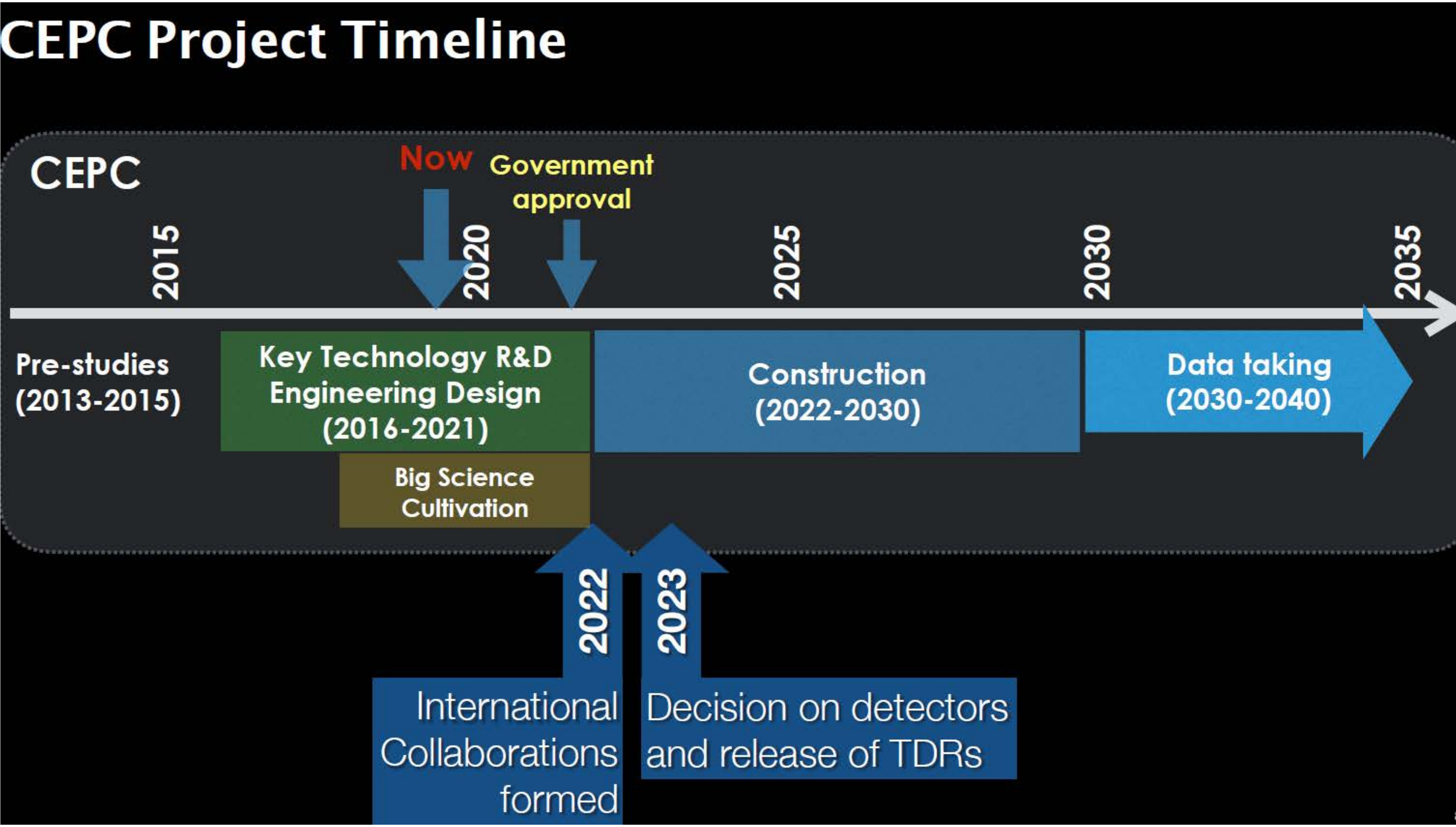


1) Qinhuangdao, Hebei Province（ Completed in 2014 ）
2) Huangling, Shanxi Province（ Completed in 2017)
3) Shenshan, Guangdong Province(Completed in 2016)
4) Baoding (Xiong an), Hebei Province (Started in August 2017)
5) Huzhou, Zhejiang Province (Started in March 2018)
6) Changchun, Jilin Province (Started in May 2018)

3

Detector summary talk from Joao

Joao's talk



Steps in the Detector R&D Program

Some update parameters of collider

Joao's talk

Updated Parameters of Collider Ring since CDR

	Higgs		Z (2T)	
	CDR	Updated	CDR	Updated
Beam energy (GeV)	120	-	45.5	-
Synchrotron radiation loss/turn (GeV)	1.73	1.68	0.036	-
Piwinski angle	2.58	3.78	23.8	33
Number of particles/bunch N_e (10^{10})	15.0	17	8.0	15
Bunch number (bunch spacing)	242 (0.68μs)	218 (0.68μs)	12000	15000
Beam current (mA)	17.4	17.8	461.0	1081.4
Synchrotron radiation power /beam (MW)	30	-	16.5	38.6
Cell number/cavity	2	-	2	1
β function at IP β_x^* / β_y^* (m)	0.36/0.0015	0.33/0.001	0.2/0.001	-
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.89/0.0018	0.18/0.0016	-
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	17.1/0.042	6.0/0.04	-
Bunch length σ_z (mm)	3.26	3.93	8.5	11.8
Lifetime (hour)	0.67	0.22	2.1	1.8
Luminosity/IP L (10^{34} $cm^{-2}s^{-1}$)	2.93	5.2	32.1	101.6

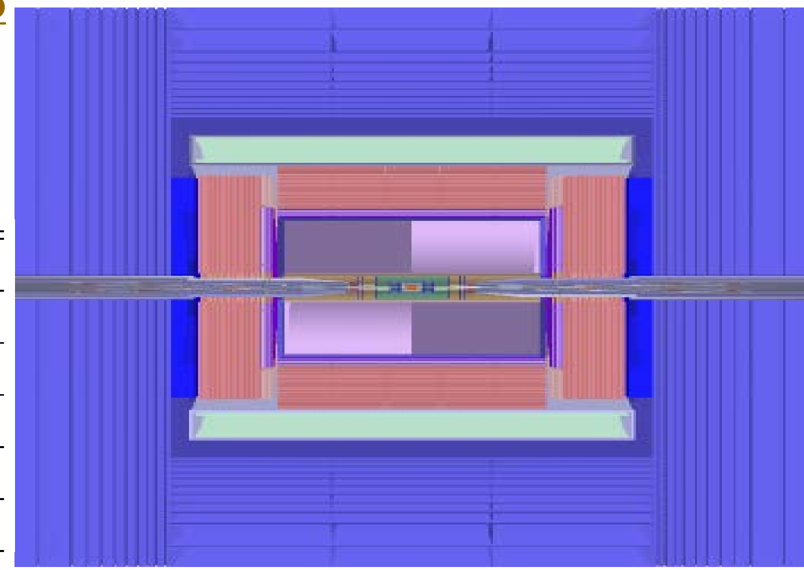
Luminosity increase factor: × 1.8 × 3.2

Three Detector Concepts (CEPC CDR)

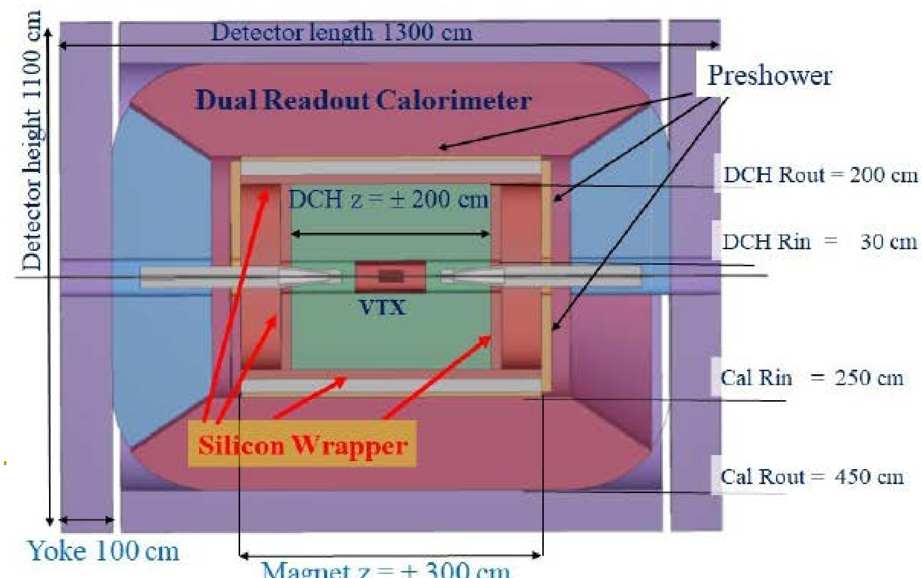
ArXiv:1811.10545

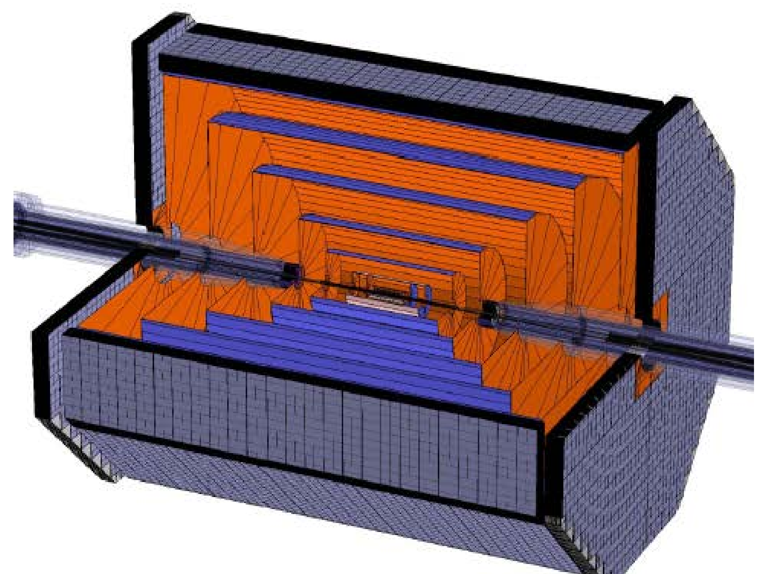
Operation mode	$\sqrt{s}$ (GeV)	L per IP (10^{34} cm^{-2}s^{-1})
H	240	3
Z	91.2	32 (*)
W^+W^-	158–172	10

- Baseline: Silicon + TPC
- FST: all-silicon tracker
- IDEA: Silicon+Drift chamber (DCH)



	Higgs	W	Z (3T)	Z (2T)
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5 × 2			





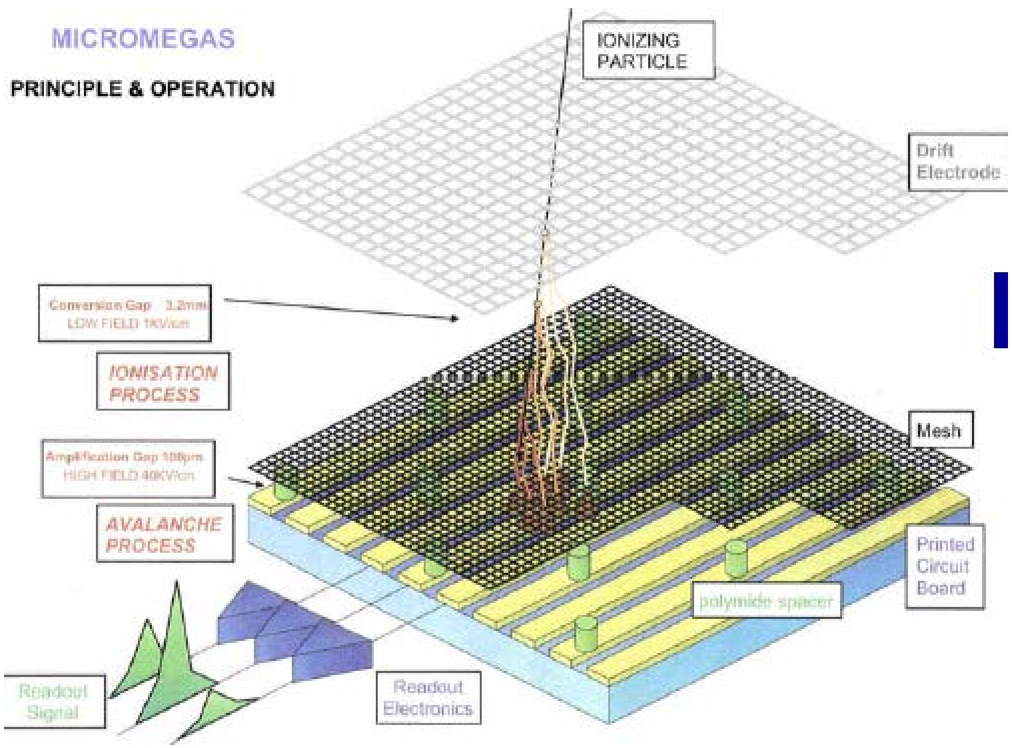
Some comments from CEPC workshop@2019.Nov.

- Machine Detector Interface
- Luminosity meter (LumiCal)
- Tracker
  - Time Projection Chamber
    - Ion back flow and field distortion is a major problem to operate at the Z pole and 2 Tesla
  - Drift Chamber
    - Can it cope with the high rates at the Z pole? Enough resolution?
- Do we really need a 3 Tesla solenoid? Why?
  - Trade-off of luminosity versus resolution and particle identification needed?
  - Can the same physics goals be achieved some other way?

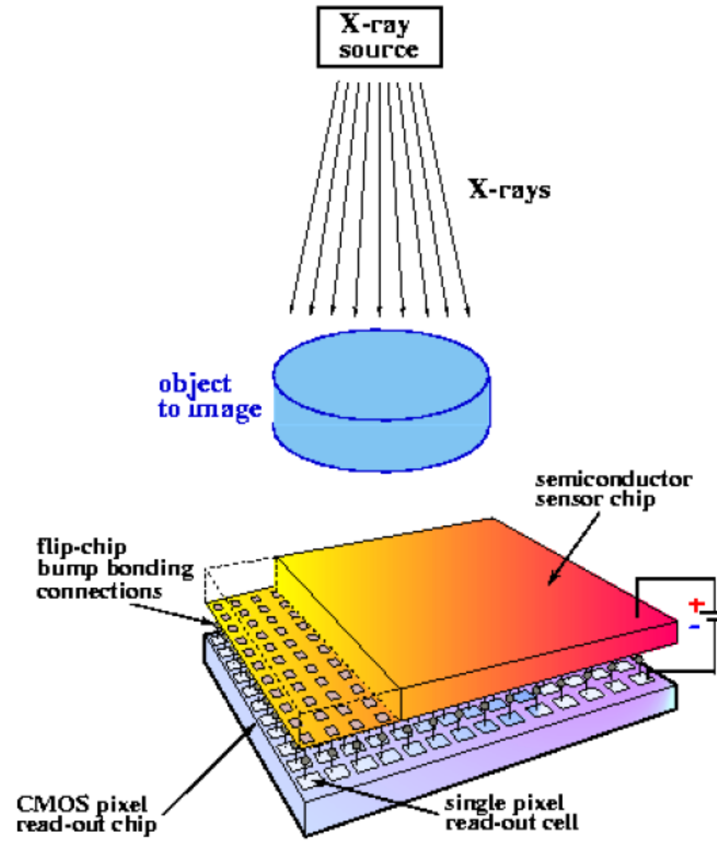
- TPC possible limitations
  - Ions back flow in chamber
  - Calibration and alignment
  - Low power consumption FEE ASIC chip

Readout of TPC

----→ Pixel R&D: Peter's talk



Standard charge collection

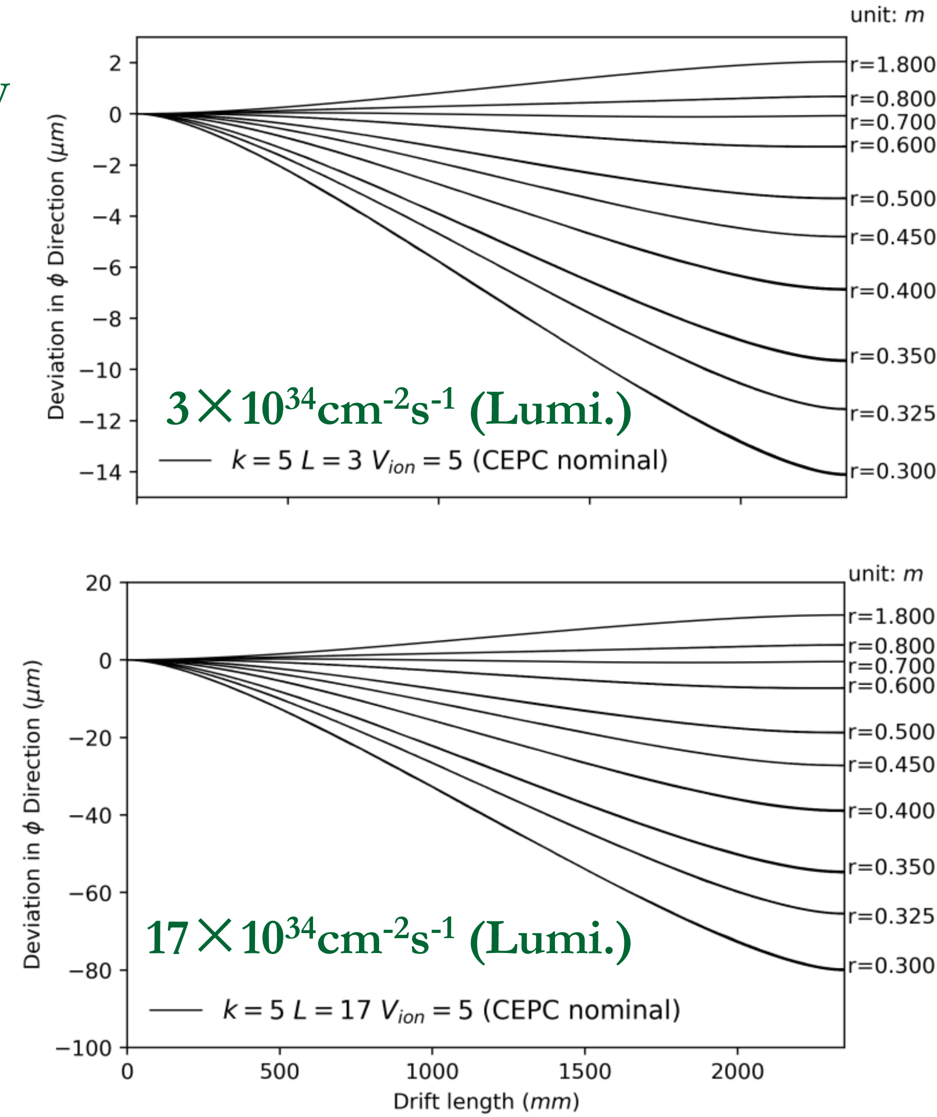


ASIC chip with sensors

Feasibility study at Z pole

DOI: 10.1142/S0217751X19400165, 2019
DOI: 10.1088/1748-0221/12/07/P07005, 2017

- **Goal:**
  - Operate TPC at higher luminosity
  - No Gating options
- Simulation
  - IBF×Gain default as the factor of 5
  - 9 thousand Z to qq events
  - 60 million hits are generated in sample
  - Average hit density: 6 hits/mm^2
  - Voxel size: 1mm×6mm ×2mm
  - Average voxel occupancy: 1.33×10^{-8}
  - Voxel occupancy at TPC inner most layer: ~2×10^{-7}
  - Validated with 3 ions disks
  - Simulation of the multi ions disk in chamber under the continuous beam structure
  - Without the charge of the beam-beam effects in TPC

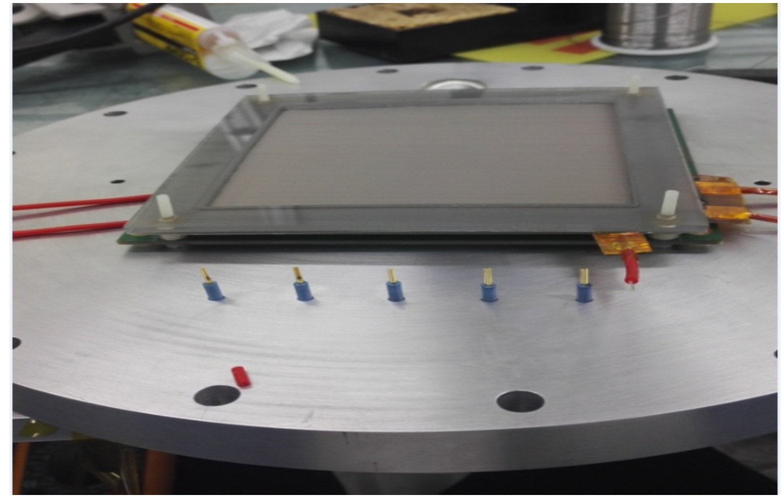


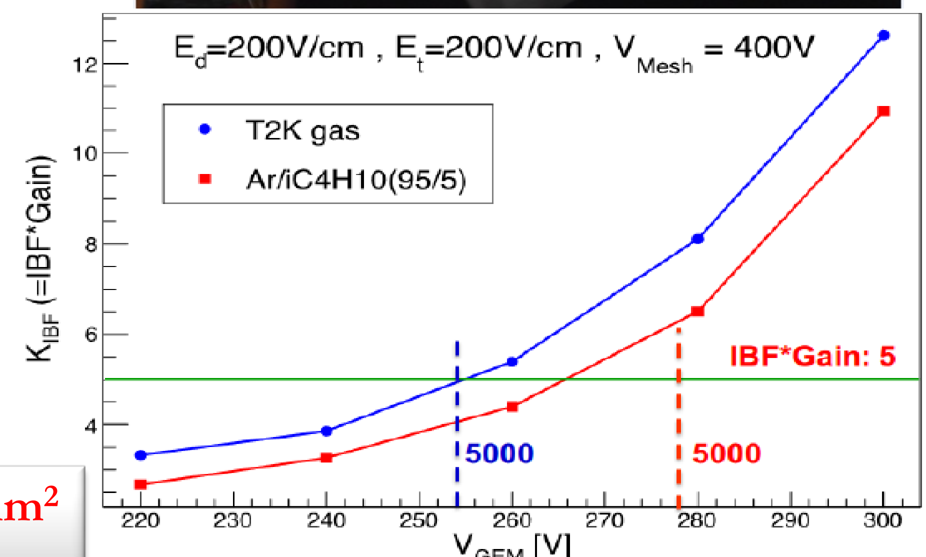
Deviation with the different TPC radius

TPC detector module R&D

DOI: 10.7498/aps.67.20172618.Acta Phys. Sin, 2018
DOI: 10.1088/1748-0221/12/04/P0401 JINST，2017
DOI: 10.7498/aps.66.072901Acta Phys. Sin. 2017
DOI: 10.1088/1674-1137/41/5/056003 , CPC,2016

- Study with GEM-MM module
  - New assembled module
  - Active area: 100mm×100mm
  - X-tube ray and 55Fe source
  - Bulk-Micromegas assembled from Saclay
  - Standard GEM from CERN
  - Avalanche gap of MM:128μm
  - Transfer gap: 2mm
  - Drift length:2mm~200mm
  - pA current meter: Keithley 6517B
  - Current recording: Auto-record interface by LabView
  - Standard Mesh: 400LPI
  - High mesh: 508 LPI





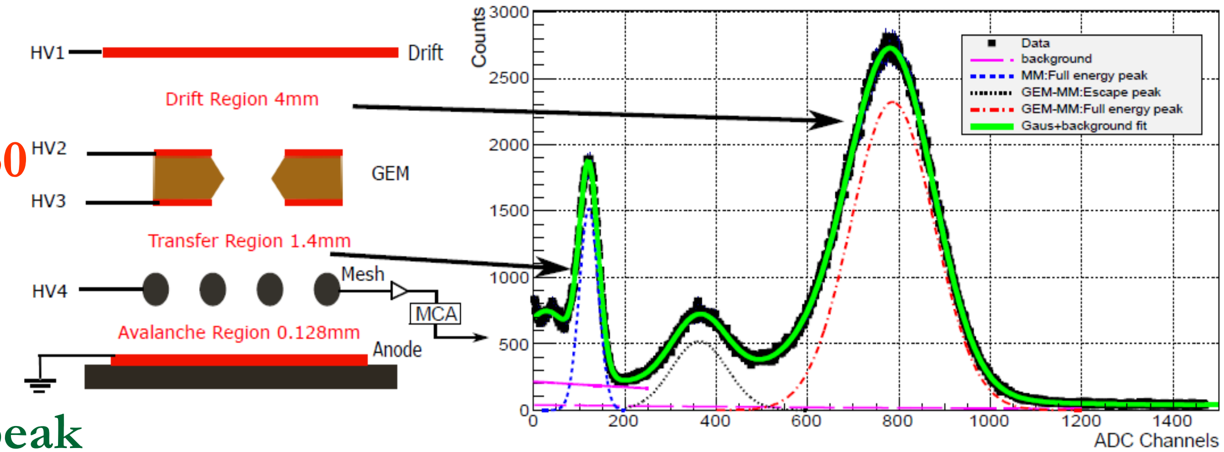
Micronegas + GEM detector module

$50\times50mm^2$ 2015-2016 → $100\times100mm^2$ 2017-2018 → $200\times200mm^2$ 2019-

GEM+MM VS TPC@ALICE

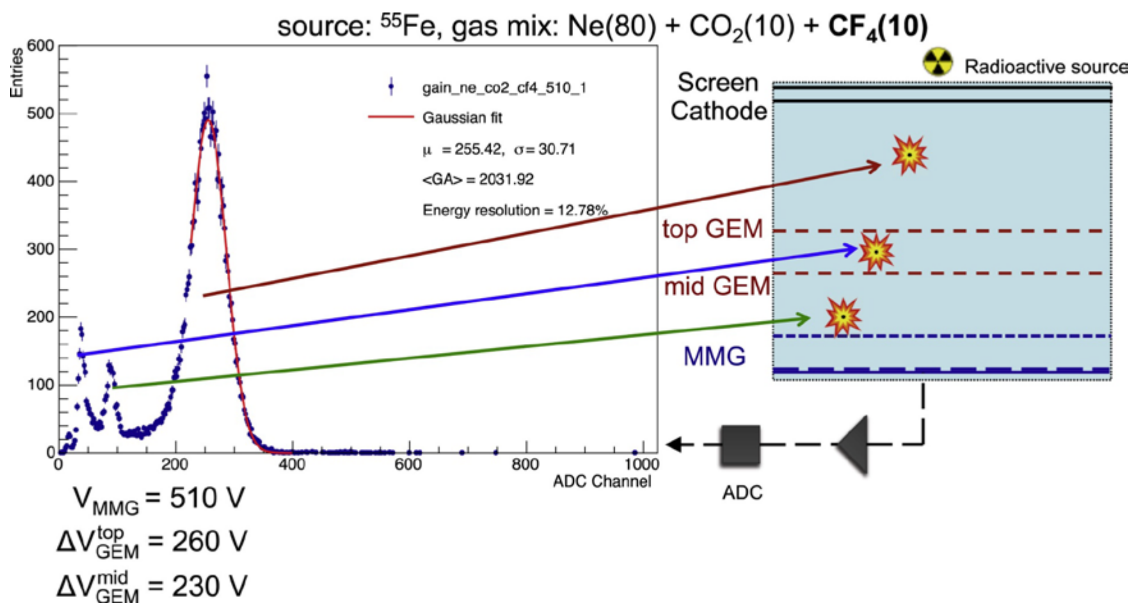
For e^+e^- machine
Primary N_{eff} is small: ~30
Pad size:1mm×6mm

GEM+MM module:
Photo peak and escape peak are clear!
Good electron transmission.
Good energy resolution.



GEM+MM IBF suppression detector@55Fe

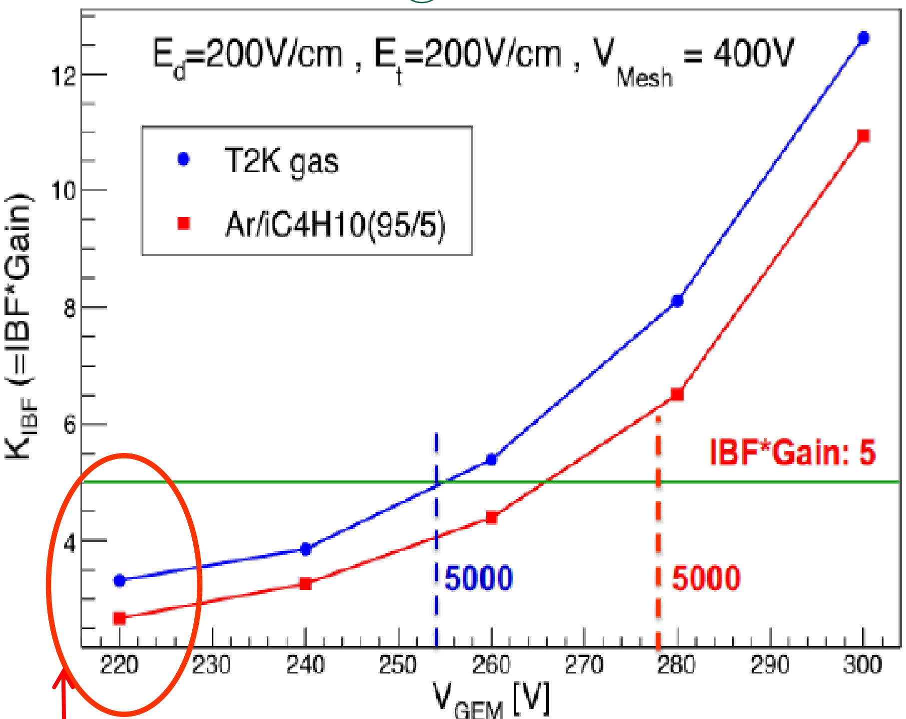
One option for ALICE TPC
GEM+GEM+MM
Gain of mid GEM: ×0.5



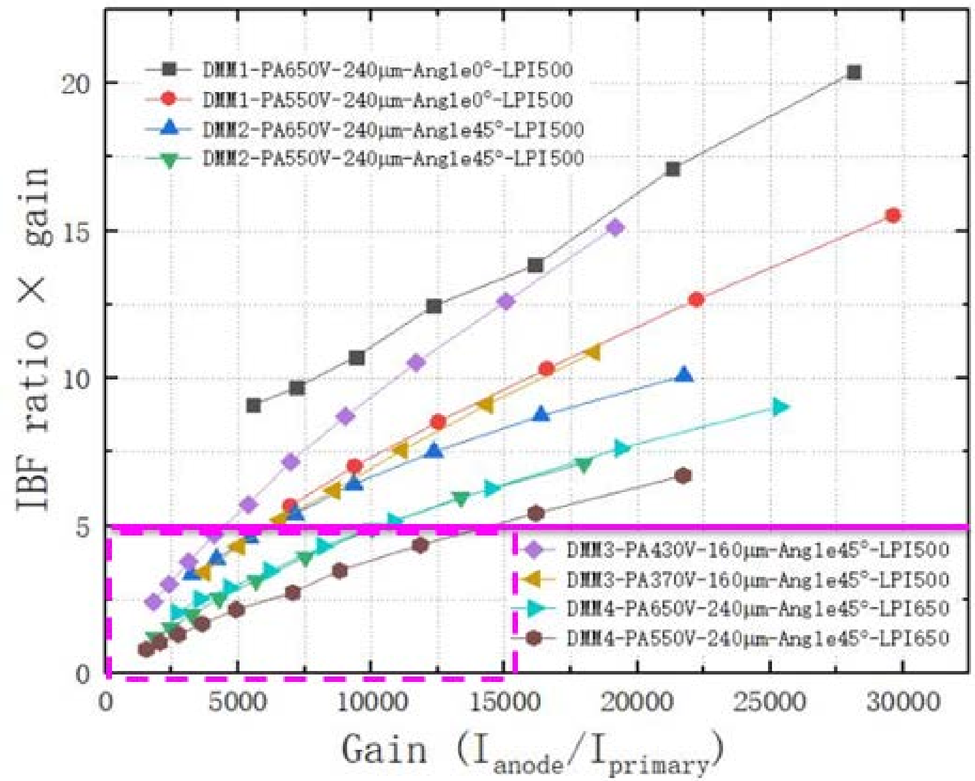
2GEM+MM IBF suppression detector@55Fe

GEM+MM VS DMM@USTC

Micronegas + GEM detector module @IHEP



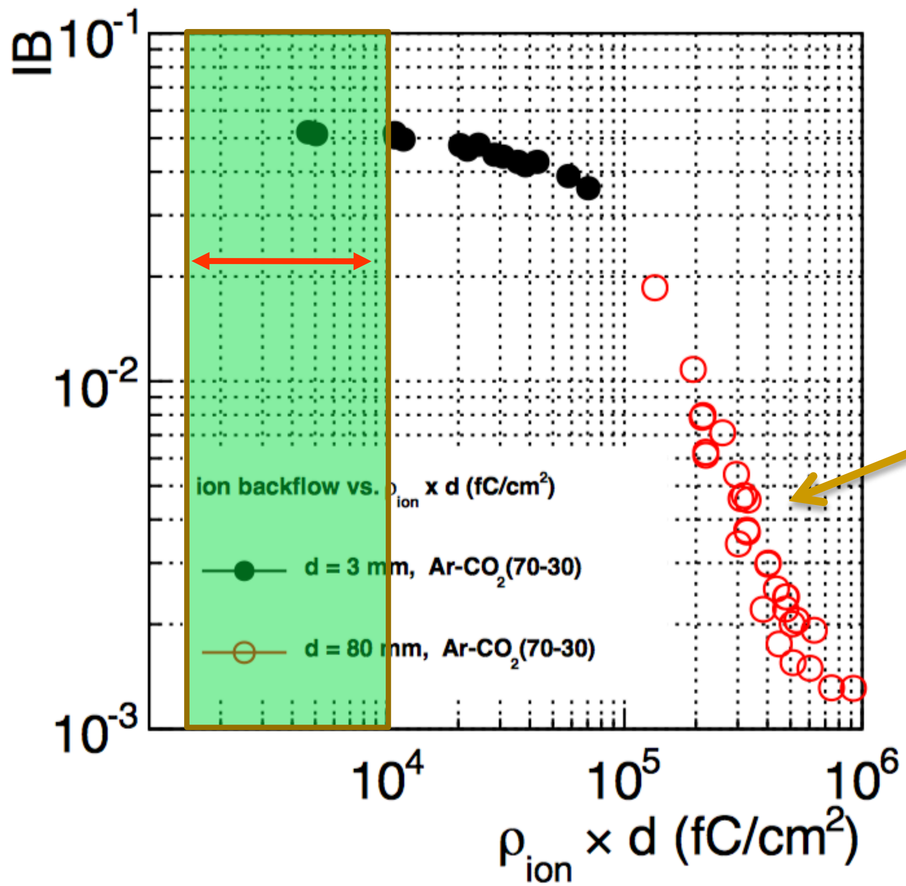
IBF of double mesh MM @USTC/Jianbei Liu

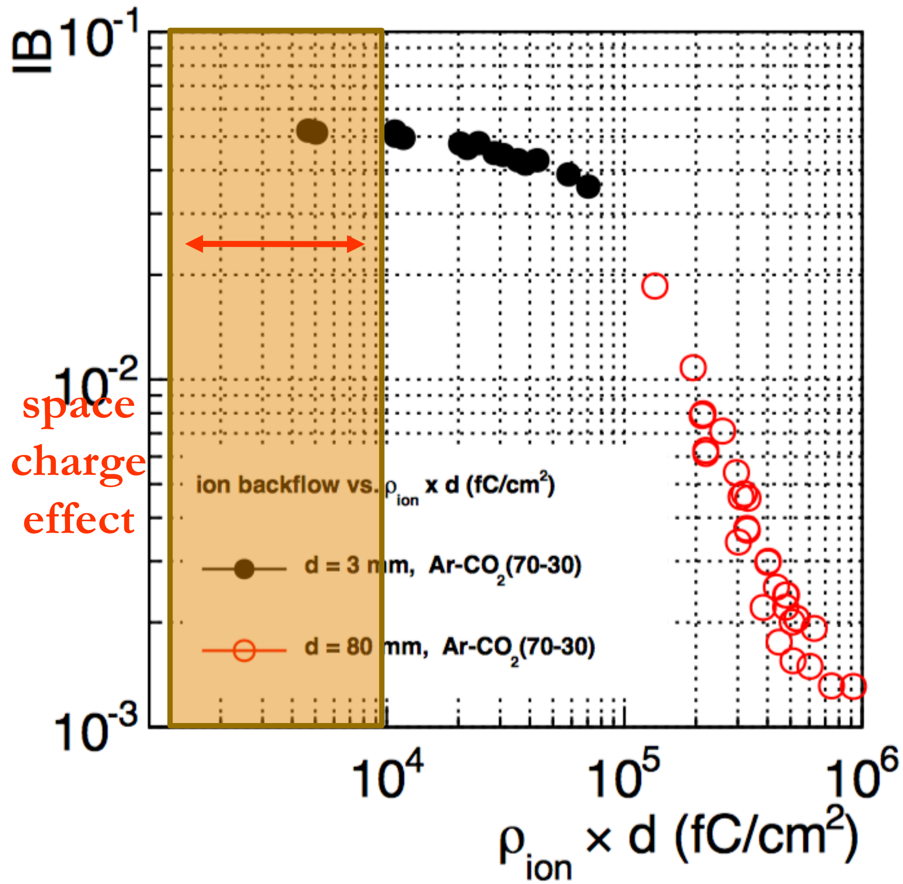


- IBF×Gain has the limitation ratio from the detector R&D at high gain.
- How to do it next ? Any new ideas? (Lower gain and no IBF)

Check $\rho_{ion}\times d$ of Space charge@ALICE

Conclusion: Current of Pad is very low in our Experiment results.
No any obvious space charge effect to decrease IBF.

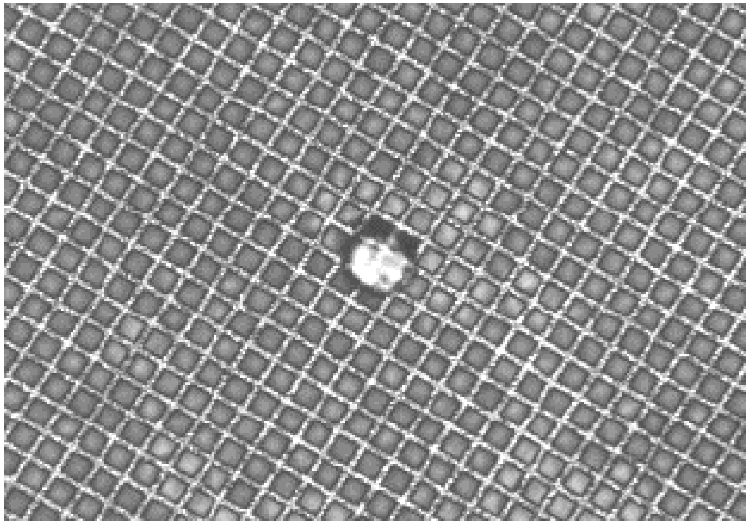


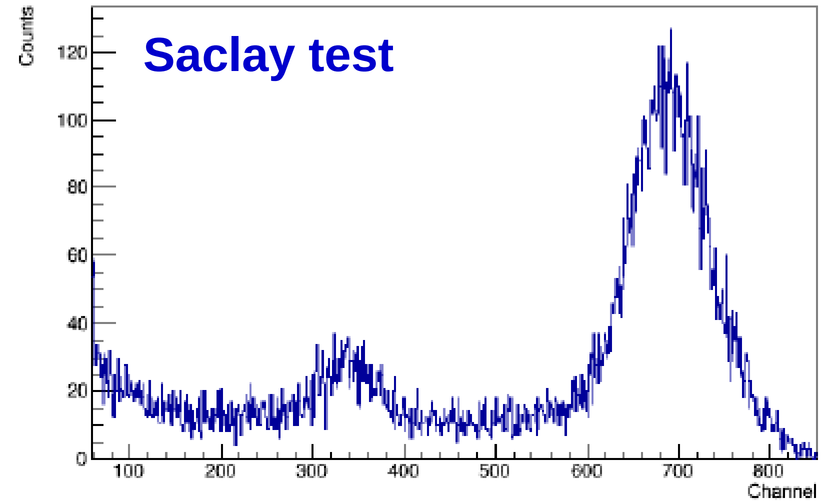


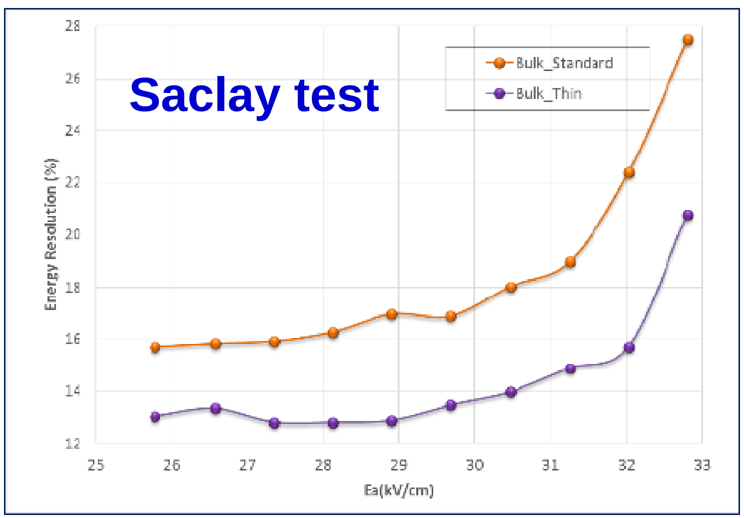
Green: T2K，Yellow: Ar/iso(95/5)

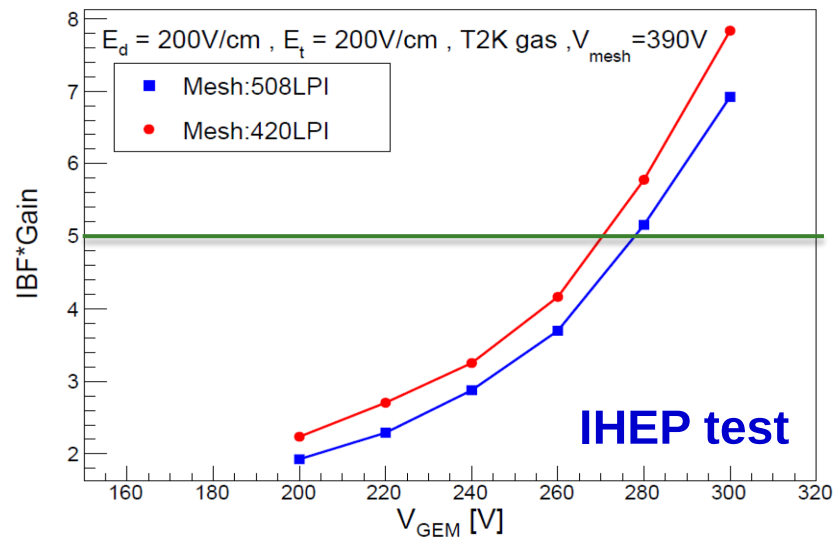
T2Kgas Ic: 4pA～59pA，～10^3 （fC/cm^2）
Ar/iso gas Ic : 3.5pA~53pA, ～10^3 （fC/cm^2）

High mesh and lower IBF@CEA-Saclay







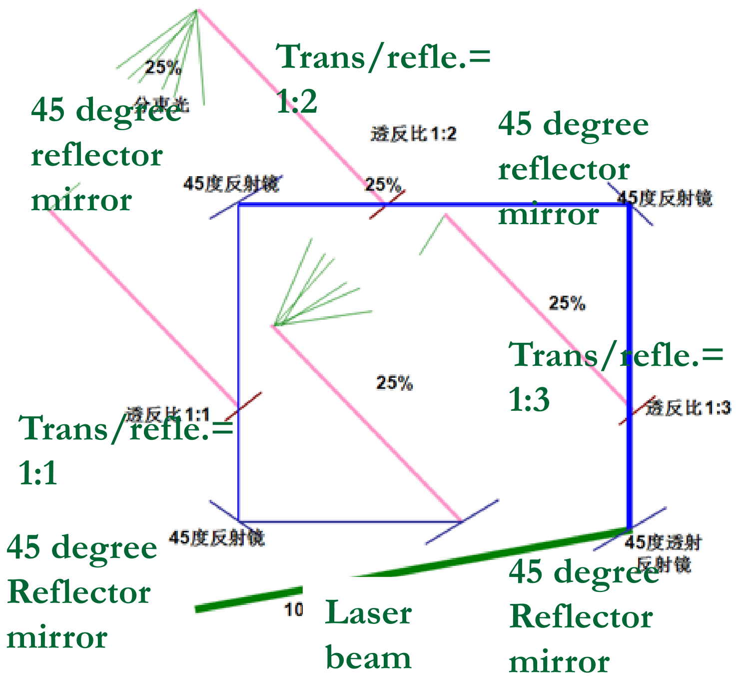


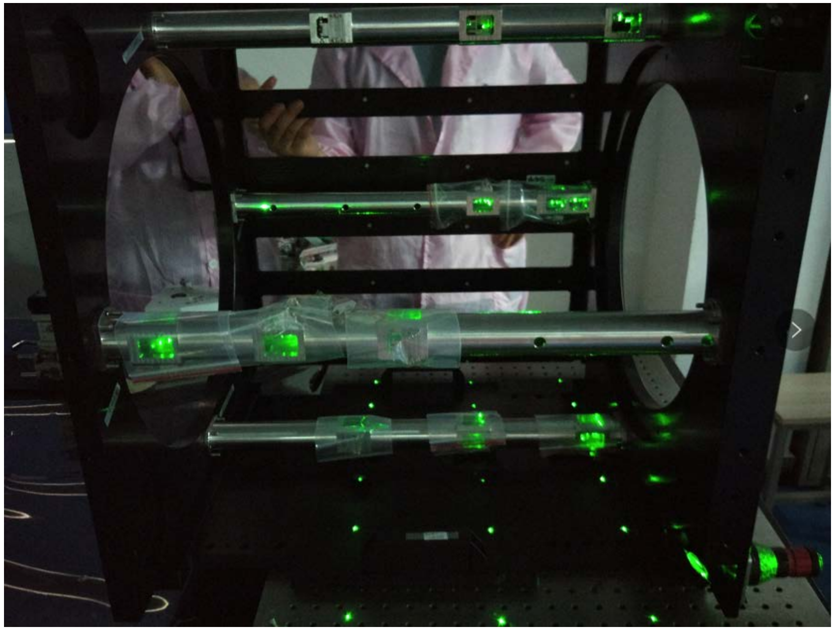
- From July, the high mesh of 508LPI has been assembled with CEA-Saclay collaboration. The preliminary results indicates that it could reach the lower IBF and better performance.

TPC detector prototype R&D

DOI: 10.7498/aps.68.20181613 (SCI) 2019
DOI: 10.1142/S0217751X19400165 (SCI) 2019
DOI: 10.1007/978-981-13-1316-5_20 (SCIE) 2018

- Study and estimation of the distortion from the IBF and primary ions with the laser calibration system
- Main parameters
  - Drift length: ~510mm, Active area: $200mm^2$
  - Integrated the laser calibration with 266nm
  - GEMs/Micromegas as the readout
  - Matched to assembled in the 1.0T PCMAG





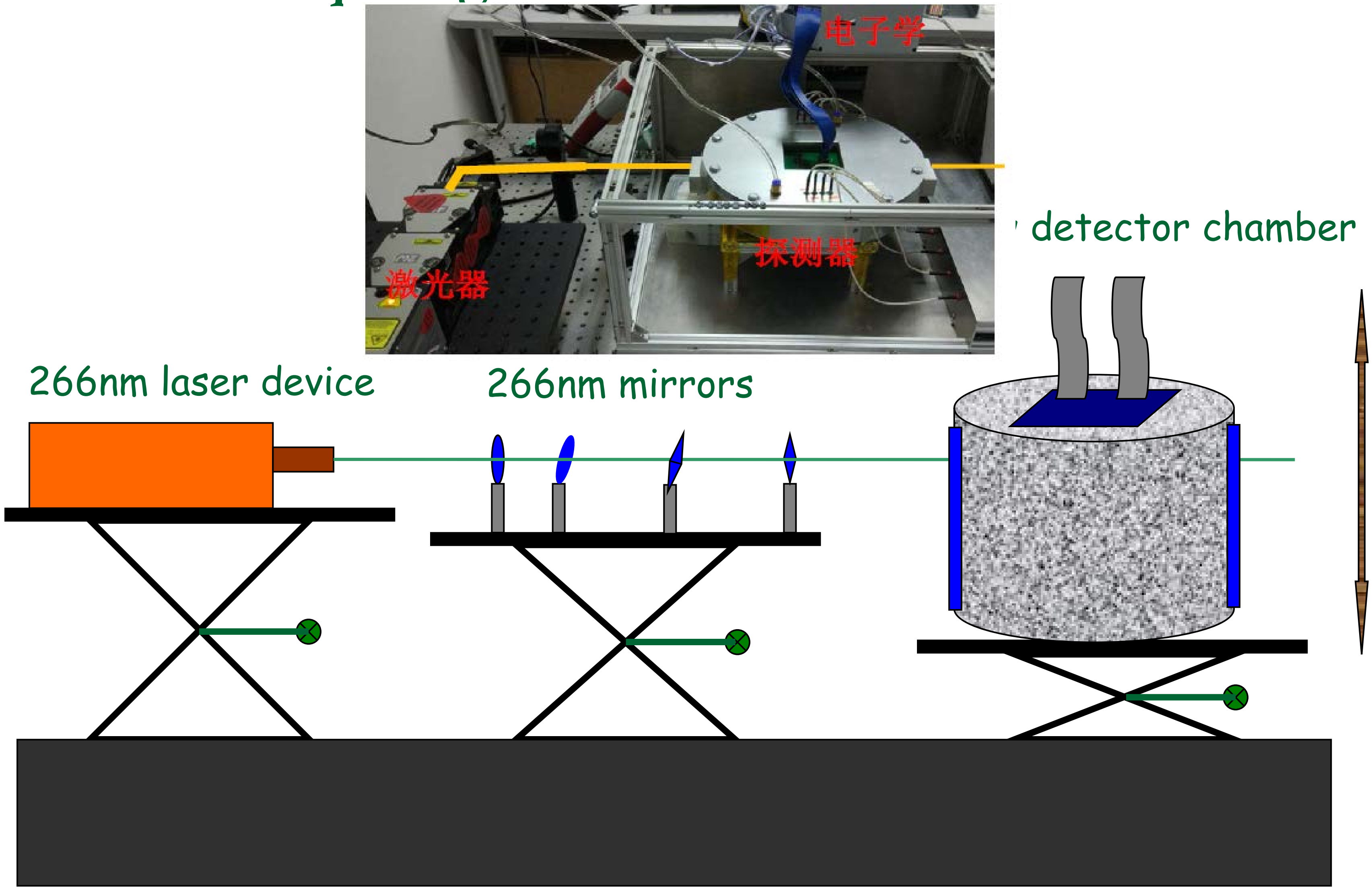
Electronics and DAQ

- Amplifier (READY)
  - CASAGEM chip
  - 16Chs/chip
  - 4chips/Board
  - Gain: 20mV/fC
  - Shape time: 20ns

- DAQ (READY)
  - FPGA+ADC
  - 4 module/mother board
  - 64Chs/module
  - Sample: 40MHz
  - 1280chs

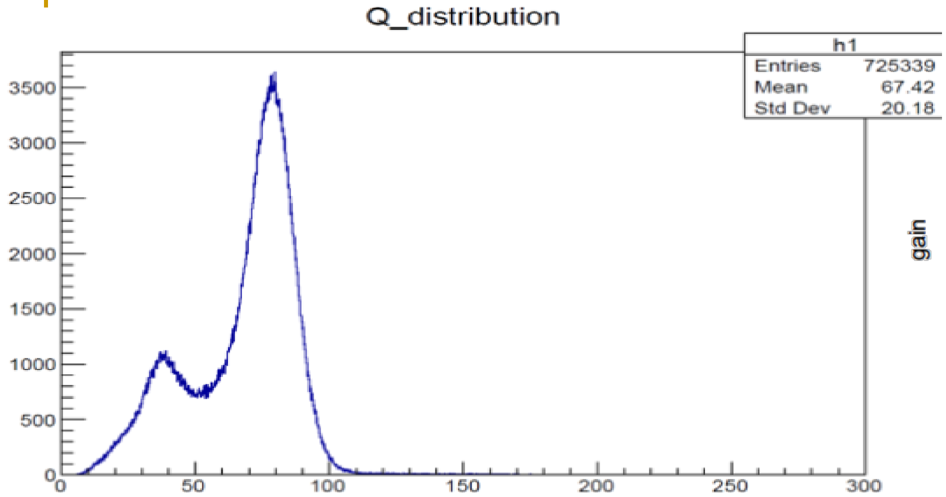
FEE Electronics and DAQ setup photos

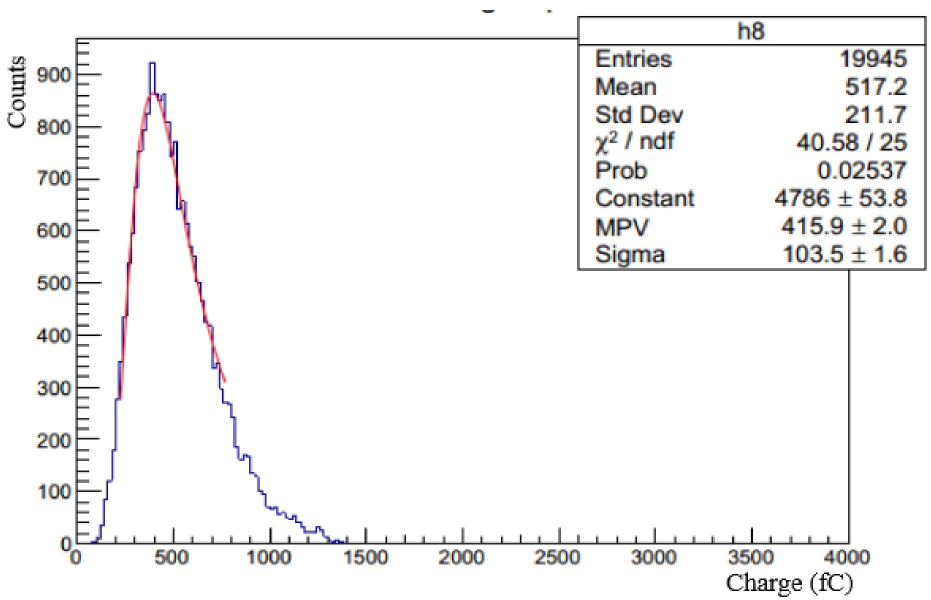
Detector setup diagram



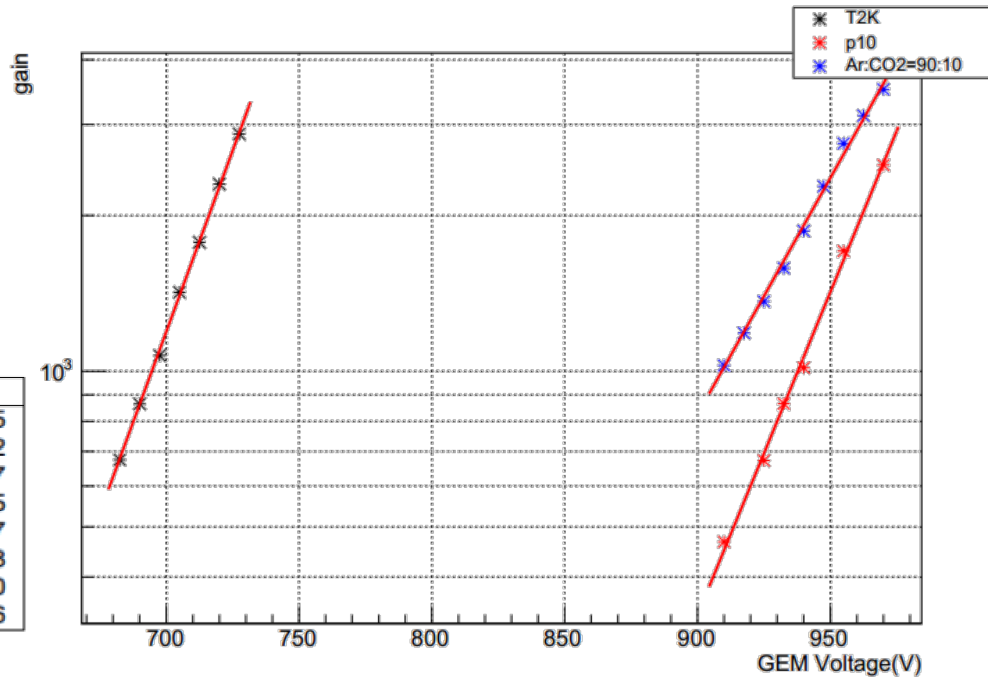
Setup and photo of the detector module

Energy spectrum and gain





Energy spectrum of 55Fe and the laser



Gain at T2K, P10, Ar/CO2

Operation gases and ionization with the laser

The three operation gases for the detector compared with ILC DESY and KEK working gas

- T2K
- P10
- Ar/CO2=90/10

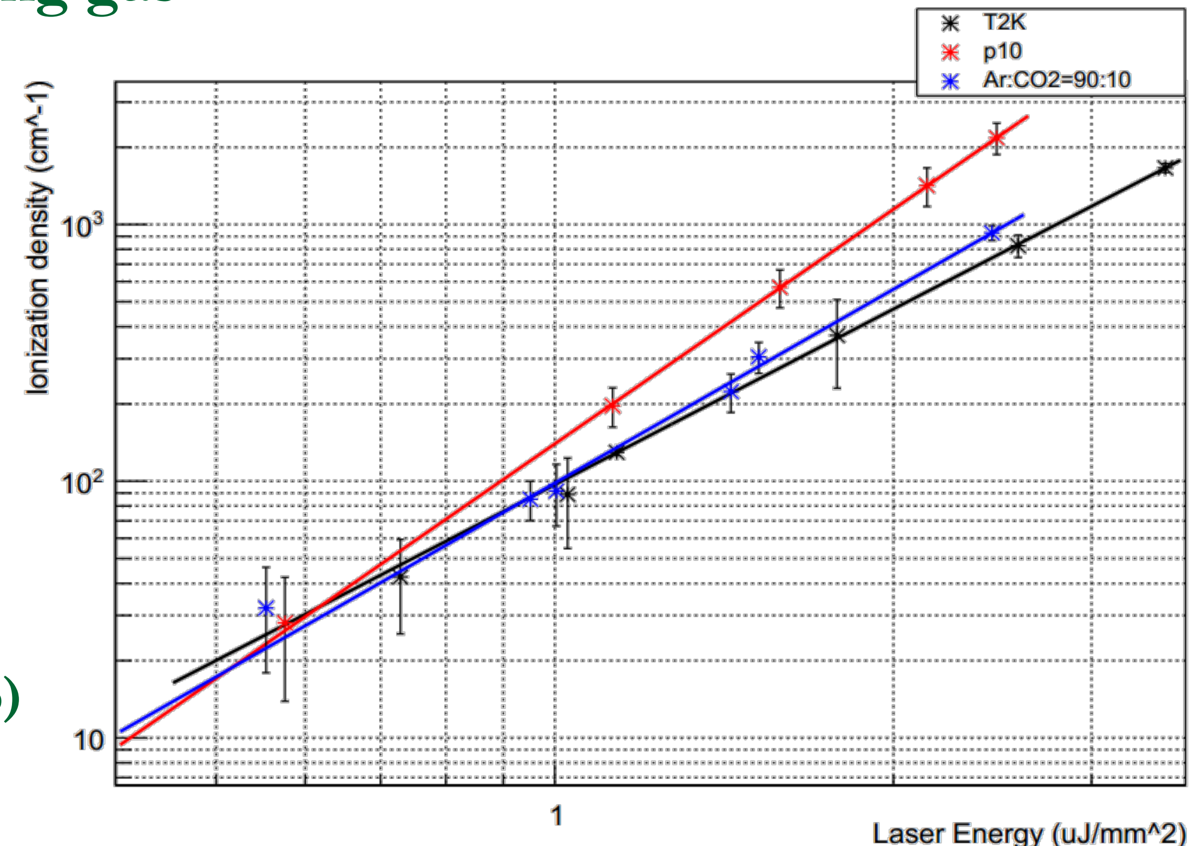
Gas purity

- Ar (99.999%)
- CO2 (99.999%)
- CH4 (99.999%)
- CF4 (99.999%)
- Isobutane (99.9%)

Ionization

- ~100 electrons/cm

at ~1uJ/mm²

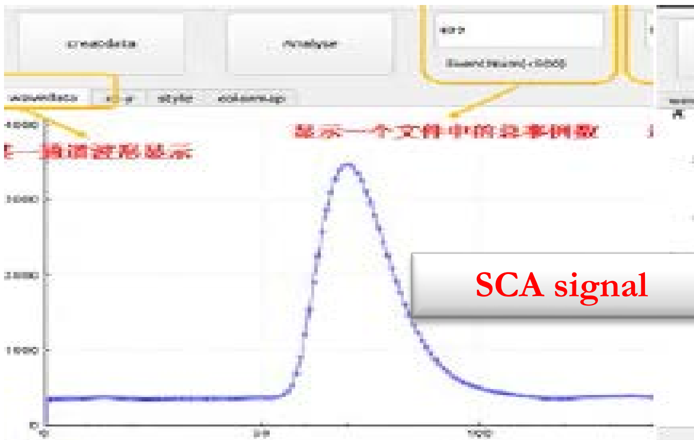


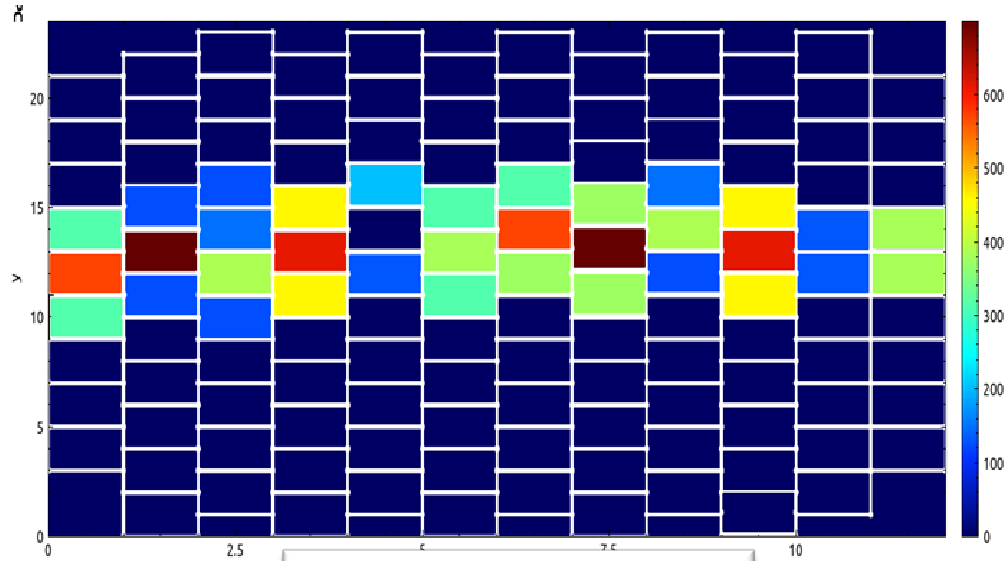
Ionization density unit: [N]/cm

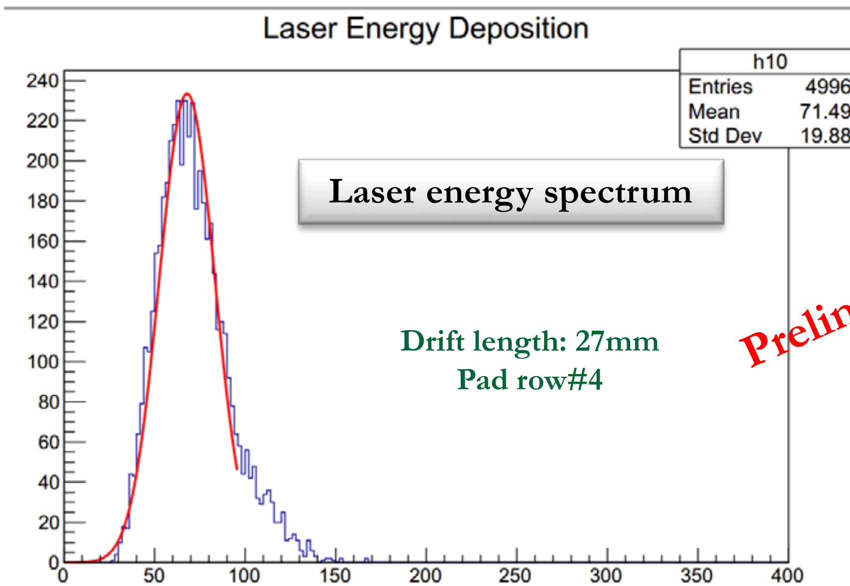
(N is the primary electron number per 0.85mm²)

Pad size: 0.9mm×6.0mm

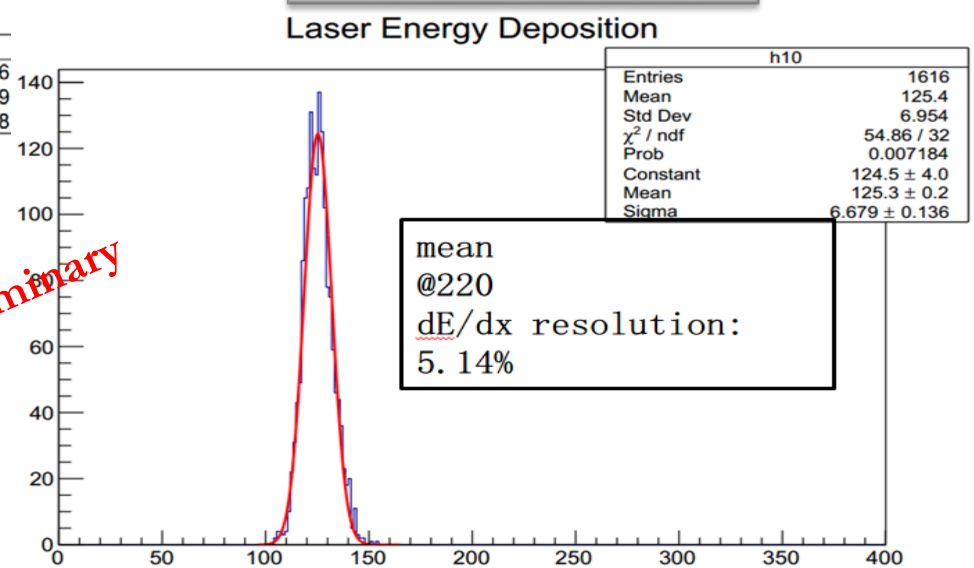
Laser track test@128chs







Preliminary

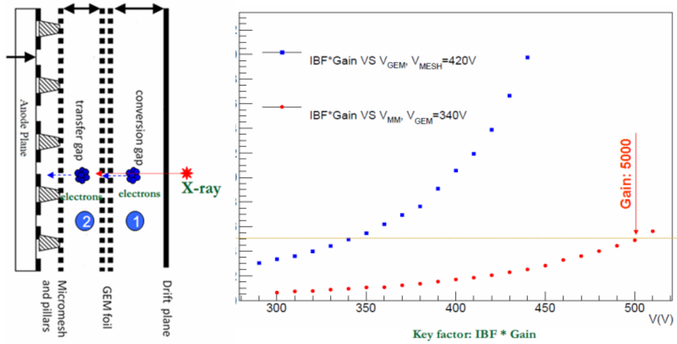


Preliminary results of Laser tracker energy spectrum and tracker

Further R&D

Continuous IBF module for CEPC:

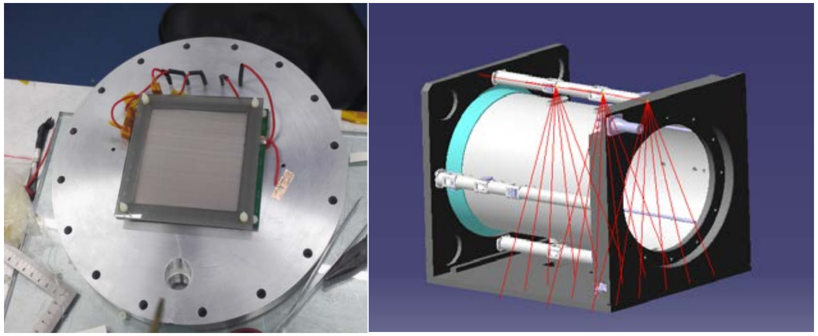
- No Gating device options used for Higgs/Z pole run
- Continuous Ion Back Flow due to the continuous beam structure (Developed in IHEP)
- ~100 μm position resolution in rφ
- Key factor: IBF×Gain=5 and leas than (R&D)
- Low discharge and spark possibility



Continuous IBF prototype and IBF×Gain

Prototype with laser calibration for CEPC :

- Calibrated drift velocity, gain uniformity, ions back in chamber
- Prototype has been designed with laser (Developed in IHEP and Tsinghua)_
- Nd:YAG laser device@266nm, 42 separated laser beam along 510mm drift length



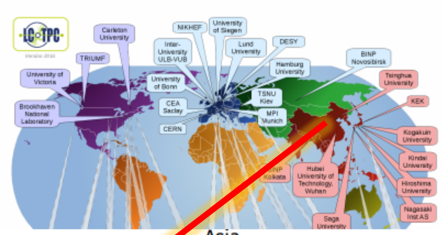
TPC prototype integrated with laser system

Collaboration:

- Joint LCTPC international collaboration to face the general TPC technology R&D
  - Some R&D for pixel TPC:
    - optimal pad size to improve track resolution, Pixel size:(200μm or large), significant reduce cost

LCTPC Collaboration Members

The map below shows the LCTPC collaboration member institutes as listed in the second Addendum of the Memorandum of Agreement from 2008.



Asia

Institute	Collaboration Board Member
Institute of High Energy Physics, CAS	Huirong Qi

Joint LCTPC international collaboration

CEPC's situation in China?

Conference @2020

- FCPPL, 27-30 Apr 2020 in Bordeaux
- CEPC Workshop EU Edition, 4-6 May 2020, Marseille
  - https://indico.in2p3.fr/event/20053/
- 2nd USA Workshop in Washington, DC - April 22-23
  - https://indico.cern.ch/event/863751/
- 4th French Summer School on "Physics of the 2 infinities“
  - First 3 weeks of July 2020, in Marseille (CPPM) and Lyon (IP2I)
  - Organized with the support of the French Embassy in China and Campus France