Performance of TPC operation at Z peak and 2 Tesla

Huirong Qi
Zhiyang Yuan, Gang Li, Manqi Ruan

19, October, 2020

Outline

- Motivation of TPC detector
- IBF suppression
- dE/dx R&D
- Magnetic field@3T/2T

Motivation

TPC limitations for Z

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

MOST1

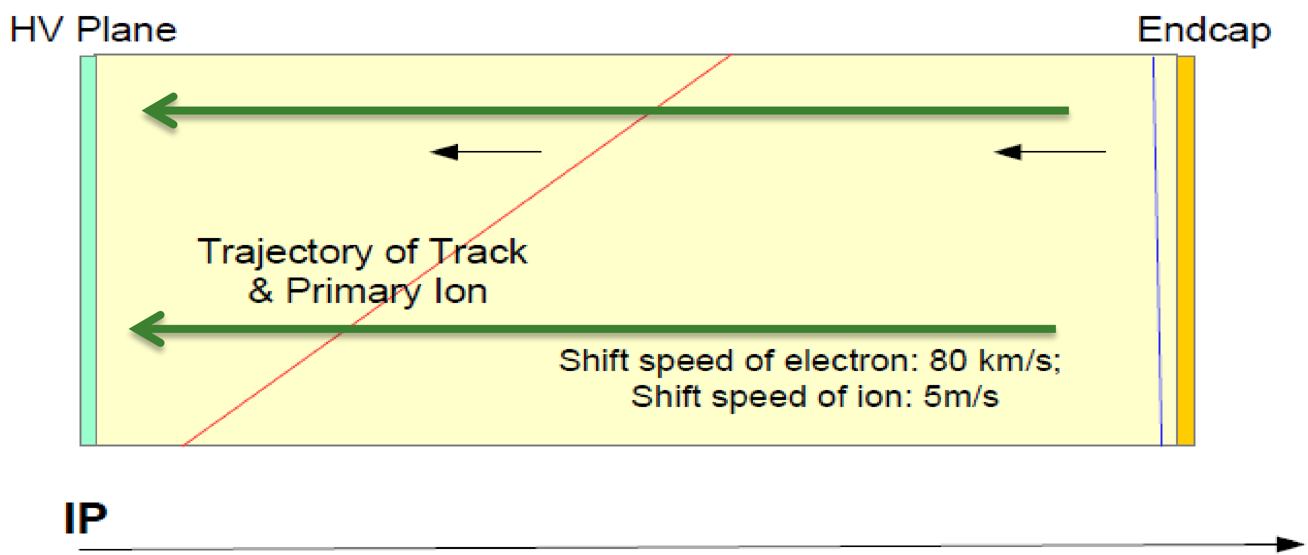
NSFC

MOST1

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

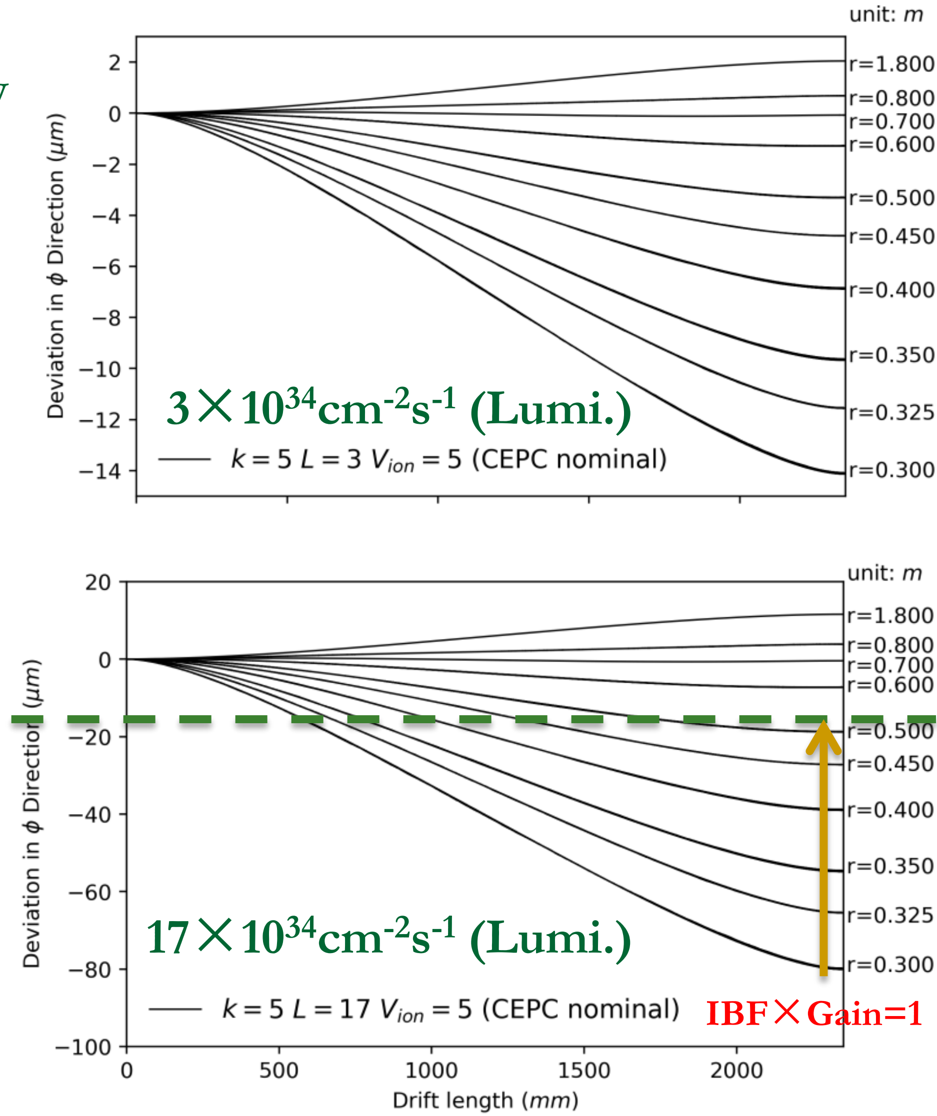


TPC detector concept

IBF simulation study at Z

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

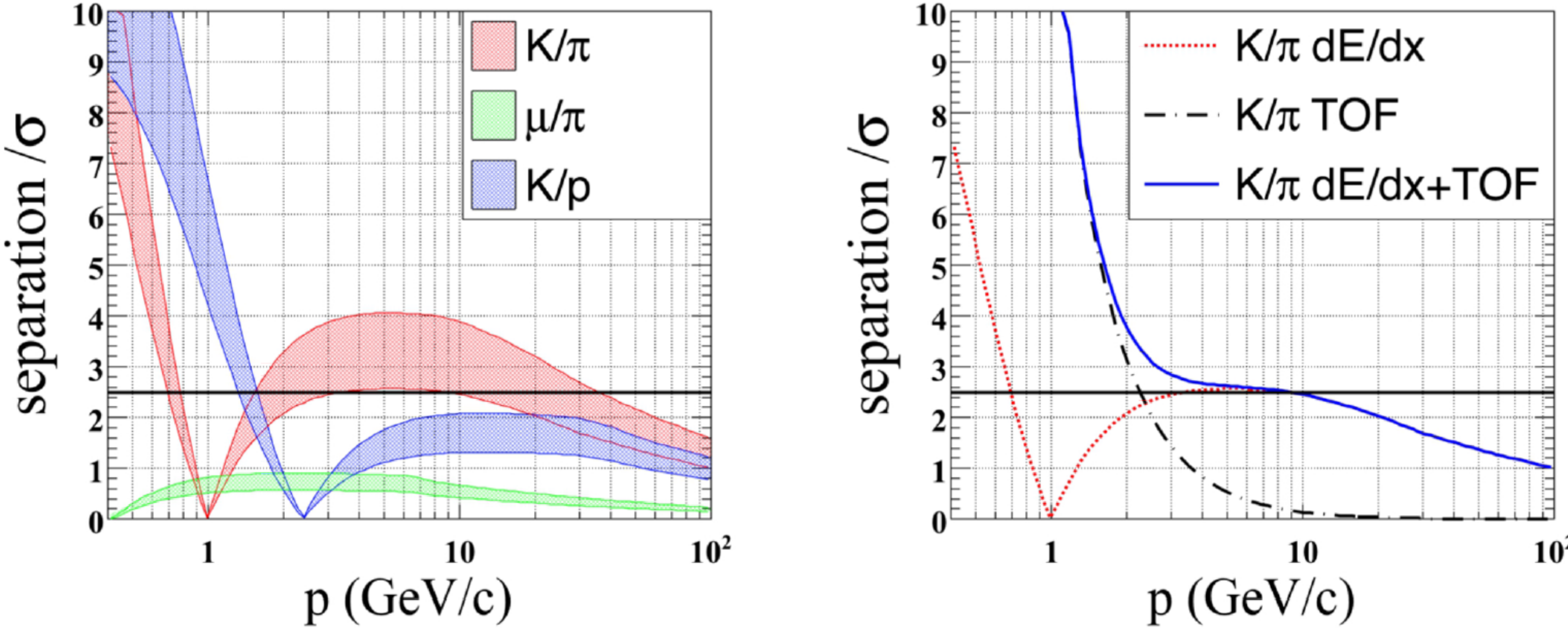


Deviation with the different TPC radius

PID requirements

Manqi@IAS meeting

Kaon



Highly appreciated in flavor physics @ CEPC Z pole

- TPC dEdx + ToF of 50 ps

At inclusive Z pole sample:

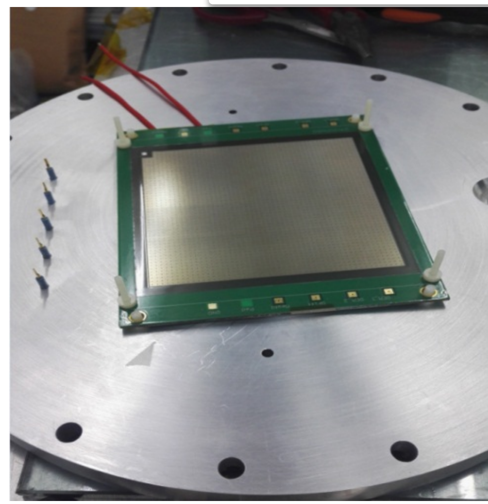
- Conservative estimation gives efficiency/purity of 91%/94% (2-20 GeV, 50% degrading +50 ps ToF)
- Could be improved to 96%/96% by better detector/DAQ performance (20% degrading + 50 ps ToF)

- **IBF suppression R&D**

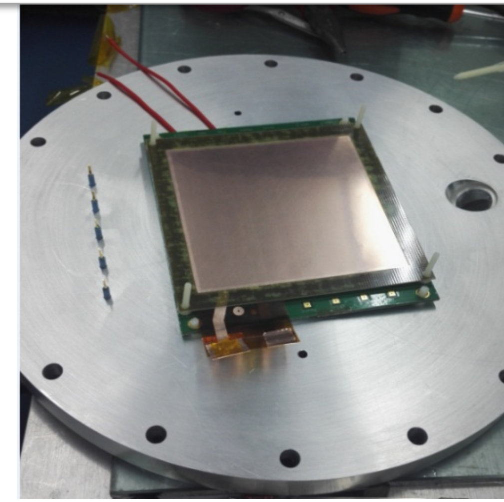
TPC detector module@ IHEP

DOI: 10.1088/1748-0221/12/04/P0401 JINST，2017.4
DOI: 10.1088/1674-1137/41/5/056003 , CPC,2016.11
DOI: 10.7498/aps.66.072901Acta Phys. Sin. 2017,7

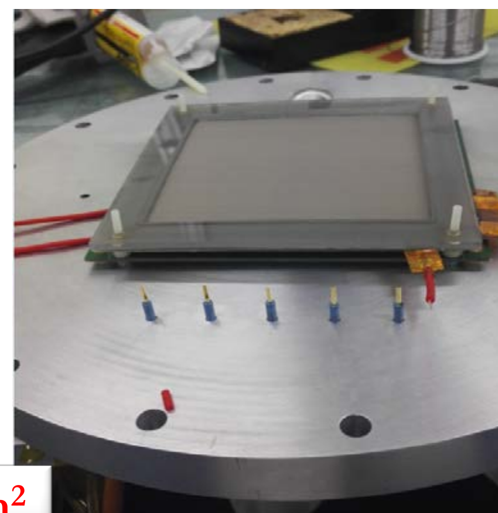
- **Study with GEM-MM module**
  - New assembled module
  - Active area: 100mm×100mm
  - X-tube ray and 55Fe source
  - Bulk-Micromegas assembled from Saclay
  - Standard GEM from CERN
  - Avalanche gap of MM:128μm
  - Transfer gap: 2mm
  - Drift length:2mm~200mm
  - pA current meter: Keithley 6517B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



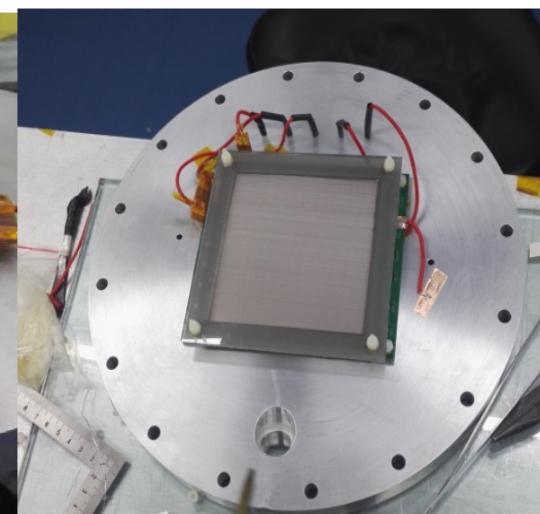
Micromegas(Saclay)



GEM(CERN)



Cathode with mesh

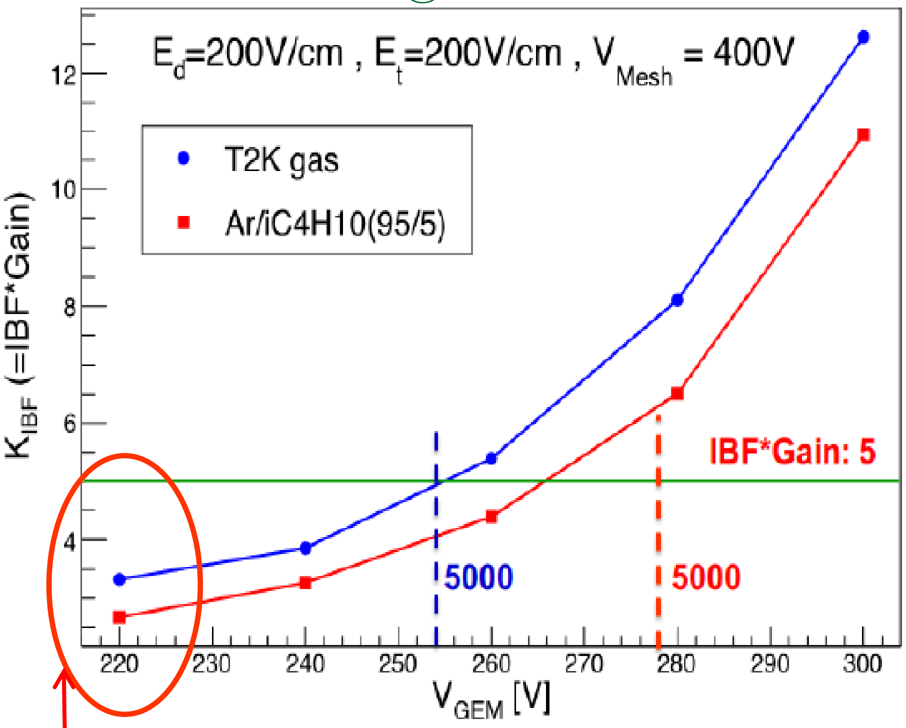


GEM-MM Detector

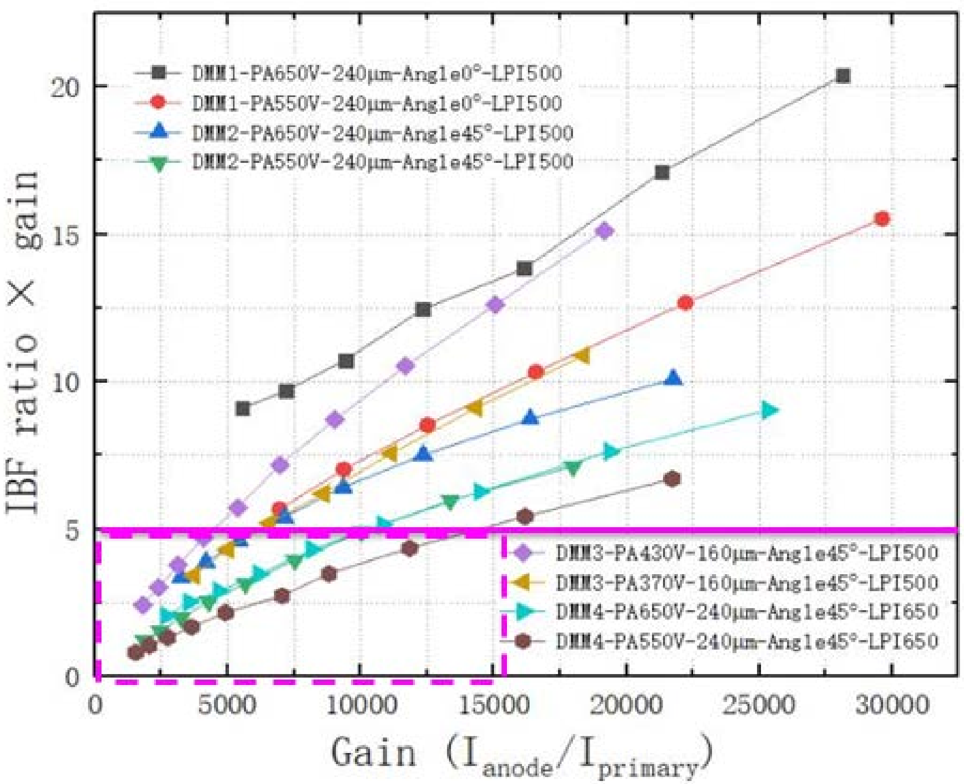
$50\times50mm^2$ 2015-2016 → $100\times100mm^2$ 2017-2018 → $200\times200mm^2$ 2019-

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.
- Lower gain and lower IBF ratio

Different concepts with IBF suppression

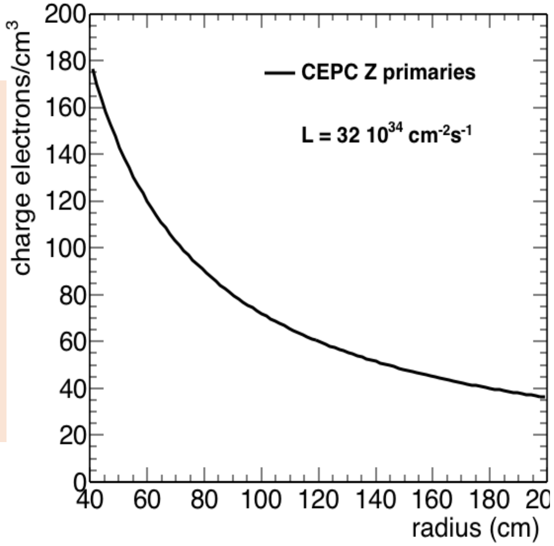
Pixel TPC with double meshes	Triple or double GEMs	Resistive Micromegas	GEM+ Micromegas	Double meshes Micromegas
IHEP, Nikehf	KEK, DESY	Saclay	IHEP	USTC
Pad size: 55um-150um square	Pad size: 1mm×6mm	Pad size: 1mm×6mm	Pad size: 1mm×6mm	Pad size: 1mm×6mm (If resistive layer)
Advantage for TPC: Low gain: 2000 IBF×Gain: -1	Advantage for TPC: Gain: 5000-6000 IBF×Gain: <10	Advantage for TPC: Gain: 5000-6000 IBF×Gain: <10	Advantage for TPC: Gain:5000-6000 IBF×Gain: <5	Advantage for TPC: High gain: 10^4 Gain: 5000-6000 IBF×Gain: 1-2
Electrons cluster size for FEE: About Ø200um	Electrons cluster size for FEE: About Ø5mm	Electrons cluster size for FEE: About Ø8mm	Electrons cluster size for FEE: About Ø6mm	Electrons cluster size for FEE: About Ø8mm
Integrated FEE in readout board Detector Gain：2000	FEE gain: 20mV/fC Detector Gain：5000-6000	FEE gain: 20mV/fC Detector Gain：5000-6000	FEE gain: 20mV/fC Detector Gain：5000-6000	FEE gain: 20mV/fC Detector Gain：5000-6000

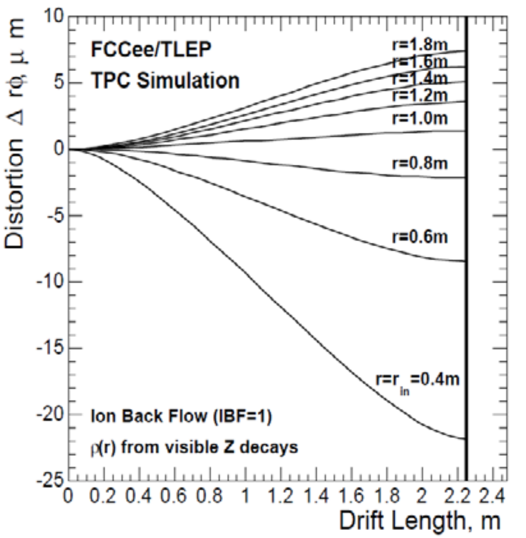
Prospects for a TPC at Z

- Rough estimations at L = $35 \cdot 10^{35}$ cm^{-2} s^{-1} indicate primary ionisation at a ILC250 level
  ⇒ < 5 µm distortions (This equals 8 µm with IBF = 1) See Arai Daisuke
- Simulation from CEPC TPC with Gain × IBF = 1 and L = $32 \cdot 10^{34}$ cm^{-2} s^{-1}
  ⇒ < 16 µm distortions (Gain × IBF = 1 and L = $32 \cdot 10^{34}$ cm^{-2} s^{-1}) from Zhiyang Yuan
- FCCee/TLEP studies at Gain × IBF = 1 and 16.8 kHz hadronic Zs by Philippe Schwemling
  ⇒ < 22 µm distortions

Rough esitimation of primary ionisation

- 10 kHz Z event rate
- 500 ms will accumulate 5000 Z events
- 20 tracks / Z event and 10 000 e / track will make 10^8 ions in volume
- Volume is ~4 10^7 resulting in 25 e/cm^3
- Similar to ILC250 accumulated charge





Slides@RD51 and TPC meeting 2020

Prospects for a TPC at future collider

Peter Kluit@TPC meeting

Potential issues → Future colliders ↓	Ions in drift chamber		Readout Occupancy
	Primary ions	Backflow ions	
ILC 1 TeV	Acceptable	GEM ion gate	Low (< 1% voxel)
CLIC 3 TeV	Requires investigation	Gating is possible	100% pads (30% voxel) 40% pixel (lower voxel)
CEPC 91 GeV ($L = 32 \cdot 10^{34}\ cm^{-2}\ s^{-1}$)	Acceptable	IBF*Gain =1 Need calibration?	Low ($< 2 \cdot 10^{-5}$ voxel)

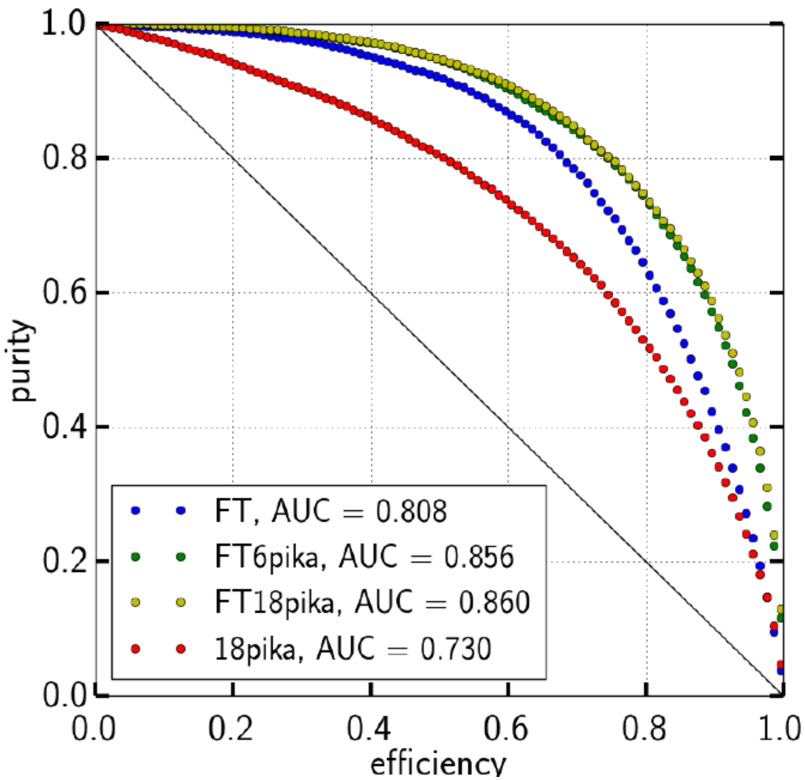
Slide from Peter and some considerations

- **dE/dx R&D**

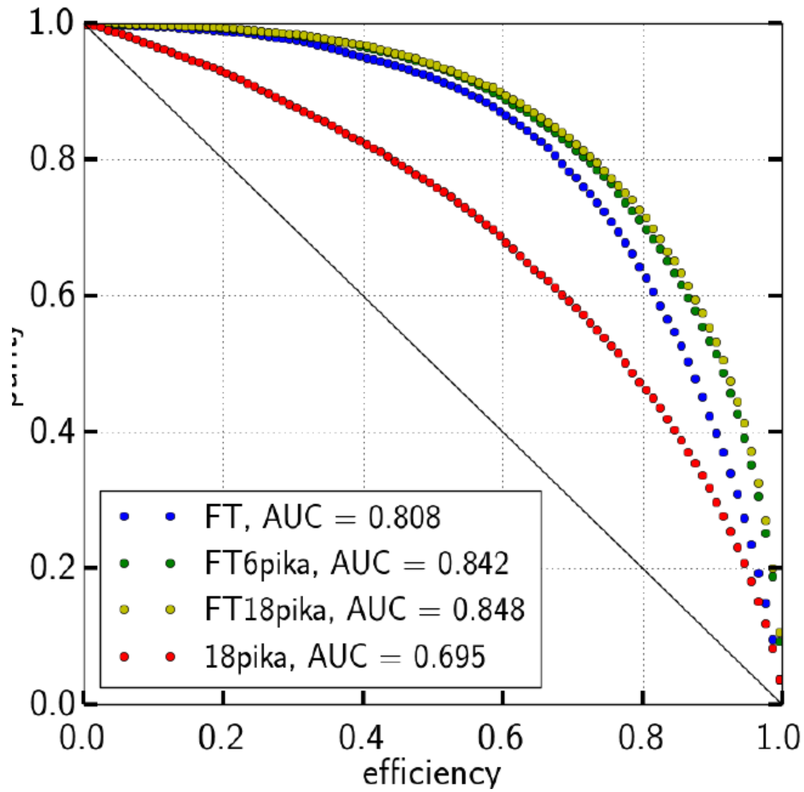
dE/dx of Flaver tag, pion, kaon

Uli Einhaus@ILD meeting

$\sigma_{dE/dx} = 2.6\%$



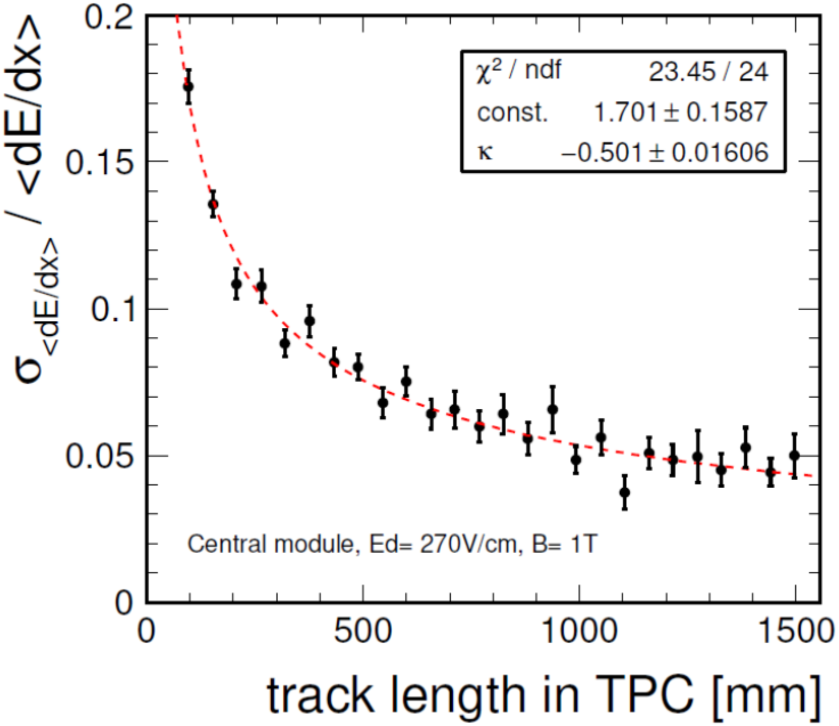
$\sigma_{dE/dx} = 4.5\%$

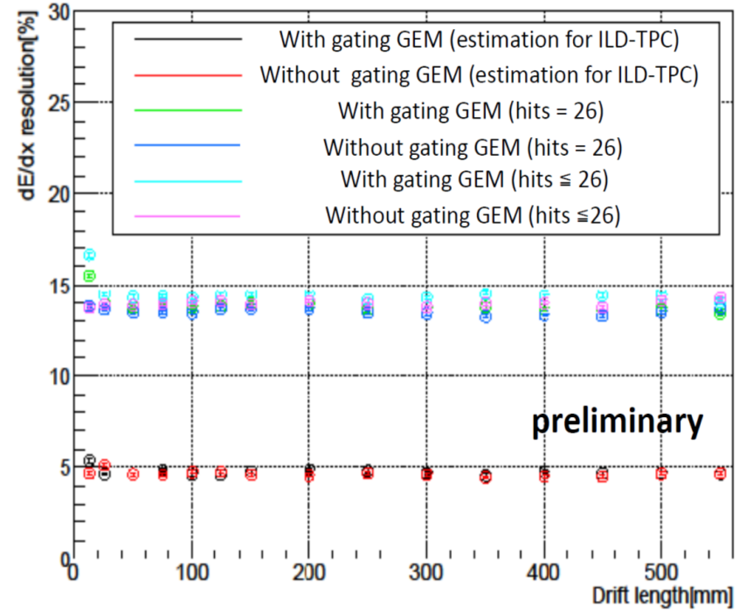


+ 20%

Beam test results@5GeV/1T/Pad TPC

Jochen@ILD meeting



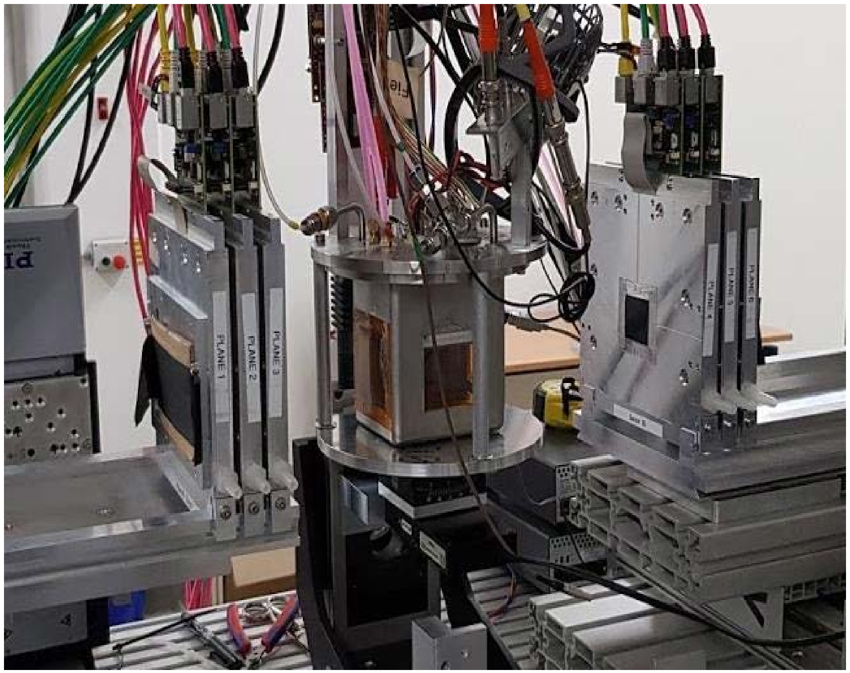


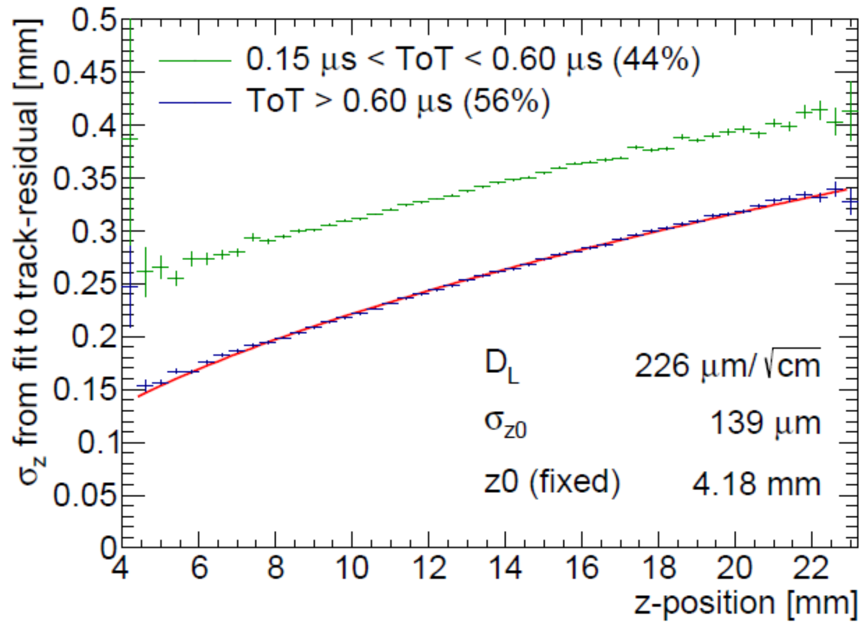
ıe average of dE/dx resolution expected from the ILD-TPC is 4.70 ± 0.02% (4.61±0.02%)
th (without) the gating GEM.

- 5GeV e- beam at DESY
- TPC detector with GEMs readout Micromegas readout

Beam test results@5GeV/1T/Pixel TPC

Peter@ILD meeting

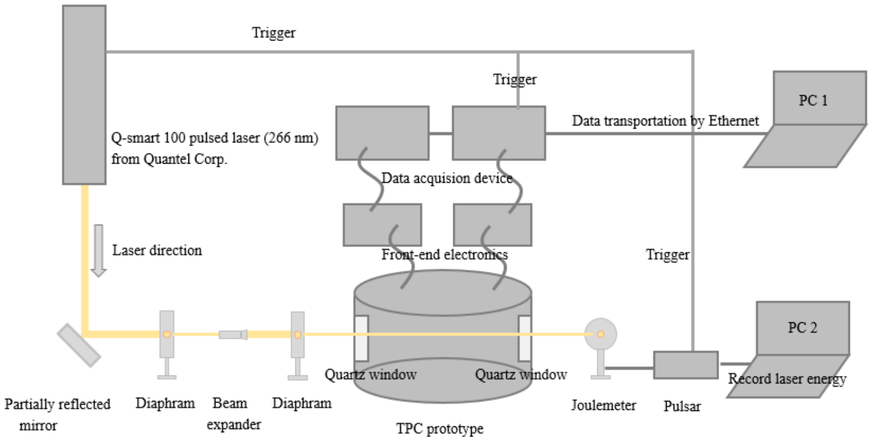


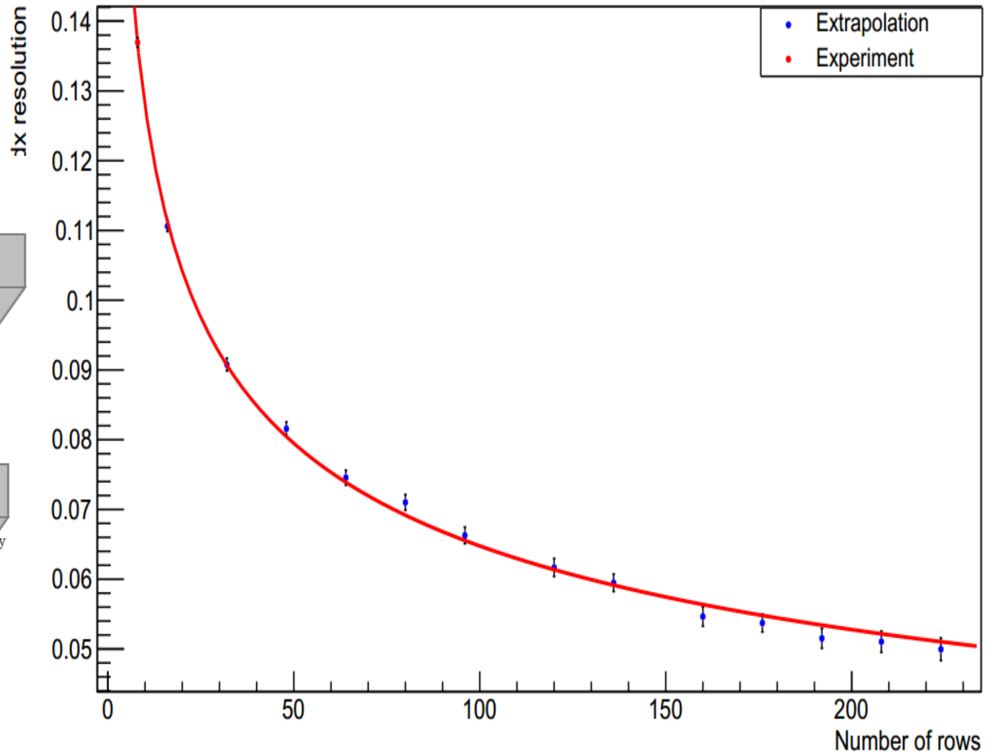


2.7% resolution is within prospects of PixelTPC [arXiv:1902.01987]

dE/dx by 266nm UV laser@IHEP

Yiming Cai, Zhiyang Yuan@ILD meeting



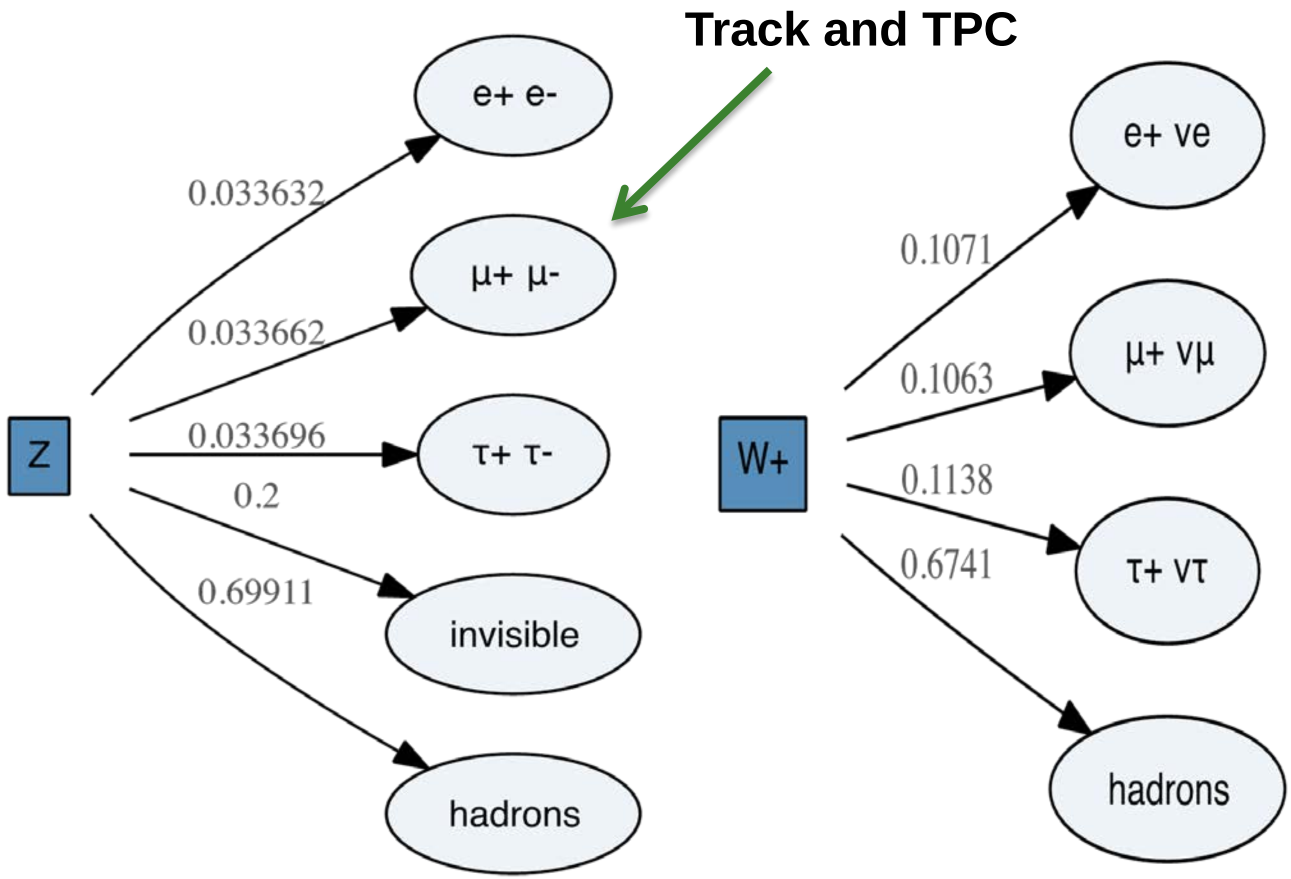


Experiment result using laser and expanded to CEPC TPC

- **Magnetic field@3T/2T**

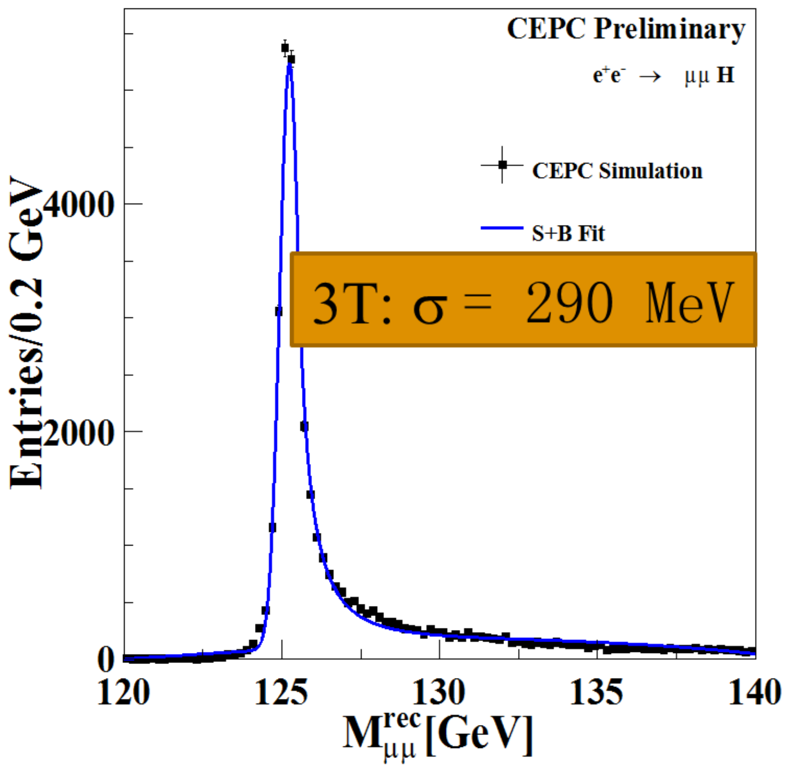
Full simulation at Z

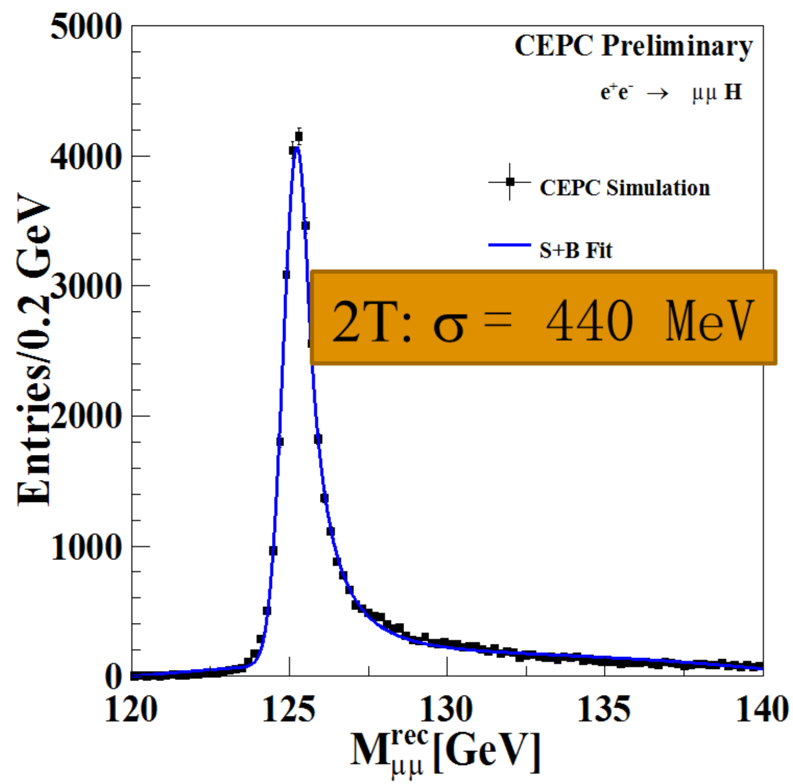
Gang Li and Zhiyang Yuan



Full simulation @3 Tesla vs. 2 Tesla @240 GeV

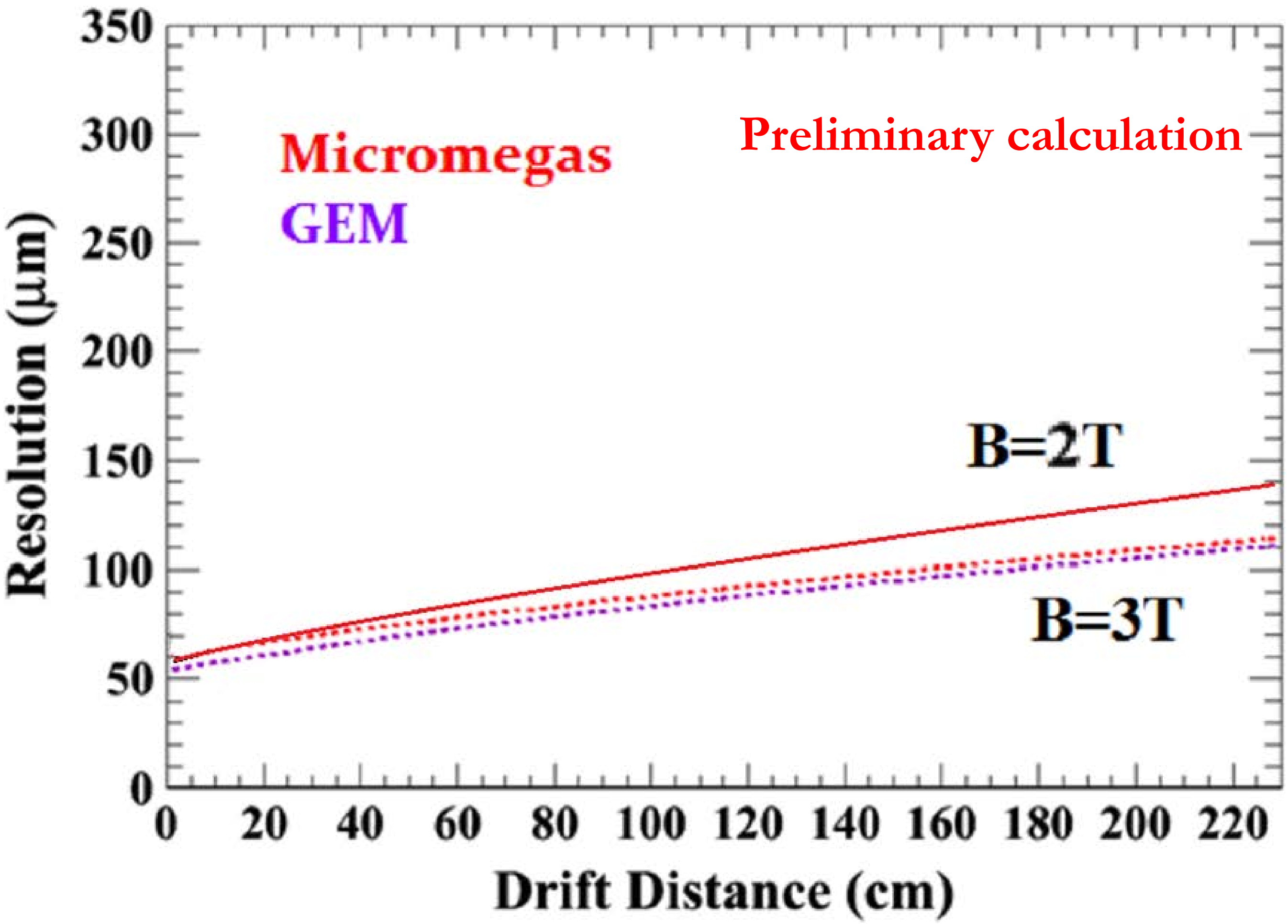
Gang Li and Zhiyang Yuan





- The δ_m of μμ recoil mass increases ~50% as expected when B = 2 T
- It needs at least 125% more data to get the same δ_m at 3 T

TPC transverse rφ resolution



Summary

- **Some motivations of TPC detector for collider at Z pole run listed.**
- **Some update results and performance of IBF, dE/dx, Magnetic field listed.**
- **TPC can meet most requirements of PID and moment resolution, and others should be optimized and R&D.**

Thanks!