TPC tracker detector for mini review

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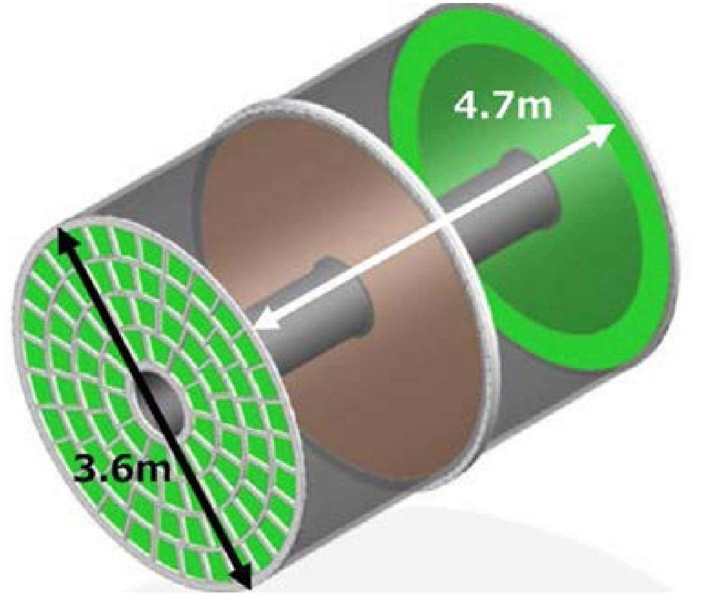
Content (TPC tracker detector)

TPC requirements for collider concept

TPC detector concept:

- **Motivated by the H tagging and Z**
- **Main tracker detector with TPC**
- **~3 Tesla magnetic field**
- **~100 μm position resolution in rφ**
- **Systematics precision (<20 μm internal)**
- **Large number of 3D points(~220)**
- **Distortion by IBF issues**
- **dE/dx resolution: <5%**
- **Tracker efficiency: >97% for pT>1GeV**



TPC detector concept

TPC could be as one tracker detector option for CEPC, 1M ZH events in 10yrs E_{cm} ≈250 GeV, luminosity ~2×10^{34} $cm^{-2}s^{-1}$, can also run at the Z-pole

Answer three key issue questions in CDR

- **Occupancy: at inner diameter**
  - Low occupancy
  - Overlapping tracks
  - Background at IP

Simulation → TPC as one option for CPEC YES or NO

- **Ion Back Flow**
  - Continuous beam structure
  - Long working time with low discharge possibility
  - Necessary to fully suppress the space charge produced by ion back flow from the amplification gap

Simulation + R&D → To control IONS
To reduce distortion

- **Calibration and alignment**
  - Complex MDI design
  - Laser calibration system

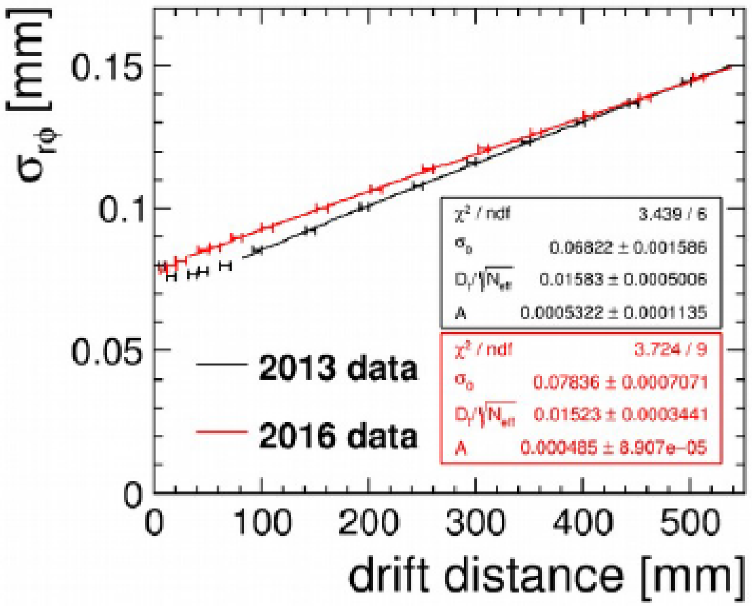
Simulation + R&D → ~100um positron resolution with calibration

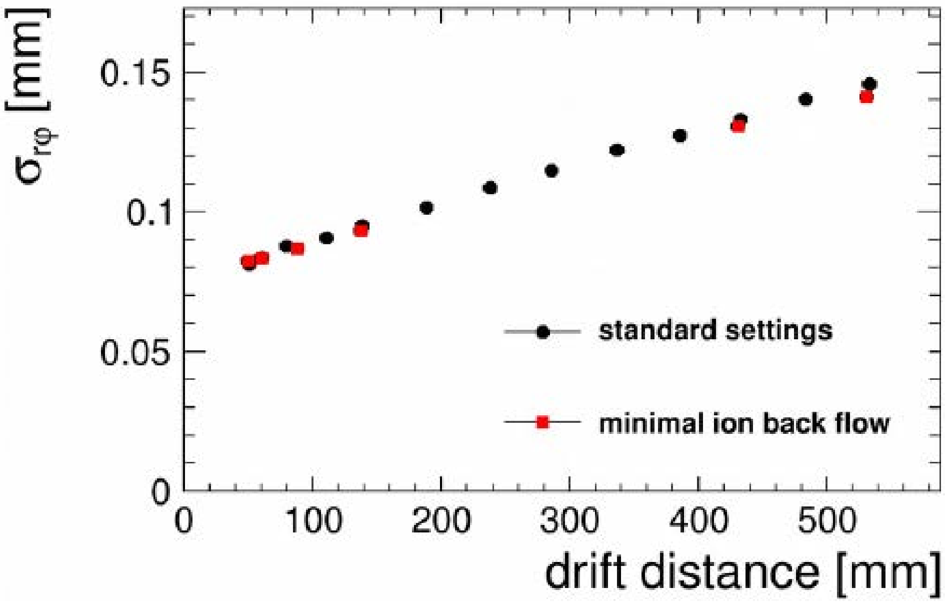
Concerning to rφ and dE/dx from LC-TPC collaboration

rφresolution of beam tests results/LC-TPC

Ralf Diener

The rφ resolution of the prototype TPC was measured using the electron beam@5GeV in a magnet field@1.0T.





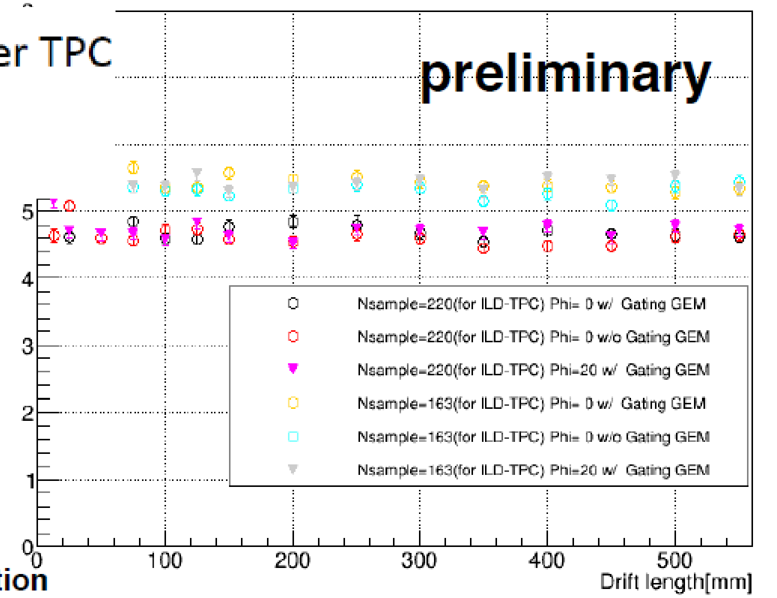
Slides from LCWS 2017 workshop in 23-27, October, 2017. Strasbourg, France

dE/dx Beam Tests Results/LC-TPC

- Resolutions extrapolated to real 220-layer TPC
  - 4% : Triple CERN GEM w/o gate
  - 4.7% : Double Scienergy GEM w/ gate

Aiko Shoji

Also, the dE/dx resolution of ILD-TPC **(small, Pad rows: 163)** was estimated by Method① and ②.



The average of dE/dx resolution

	Method① Sampling	Method② Scaling
w/ gating GEM, ϕ= 0°	5.46 ± 0.02%	5.49 ± 0.01 %
w/o gating GEM, ϕ= 0°	5.35 ± 0.02%	5.40 ± 0.01%
w/ gating GEM, ϕ= 20°	5.42 ± 0.02%	5.49 ± 0.01%

① and ②: consistent

TPC radius: 1.8m

The dE/dx resolution of the ILD-TPC (large-model) with a gating GEM was estimated to be about 4.7 % for 5 GeV/c electrons on the Fermi plateau. In the small-model TPC, the dE/dx resolution was estimated to be about 5.5 %.

TPC radius: 1.6m

Slides from LCWS 2017 workshop in 23-27, October, 2017. Strasbourg, France

CEPC Detector for CDR

Manqi's talk

Feasibility & Optimized Parameters

√ Feasibility analysis: TPC and Passive Cooling Calorimeter is valid for CEPC

	CEPC_v1 (~ ILD)	Optimized (Preliminary)	Comments
Track Radius	1.8 m	>= 1.8 m	Requested by Br(H->di muon) measurement
B Field	**3.5 T**	**3 T**	**Requested by MDI**
ToF	**-**	**50 ps**	**Requested by pi-Kaon separation at Z pole**
ECAL Thickness	84 mm	84(90) mm	84 mm is optimized on Br(H->di photon) at 250 GeV;
ECAL Cell Size	5 mm	10 – 20 mm	Passive cooling request ~ 20 mm. 10 mm should be highly appreciated for EW measurements – need further evaluation
ECAL NLayer	30	20 – 30	Depends on the Silicon Sensor thickness
HCAL Thickness	**1.3 m**	**1 m**	-
HCAL NLayer	**48**	**40**	Optimized on Higgs event at 250 GeV;

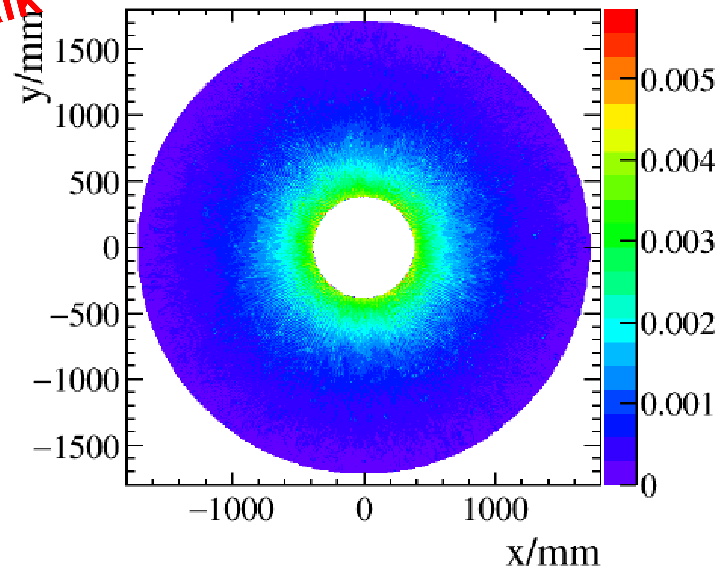
High rate at Z pole

ArXiv: 1704.04401

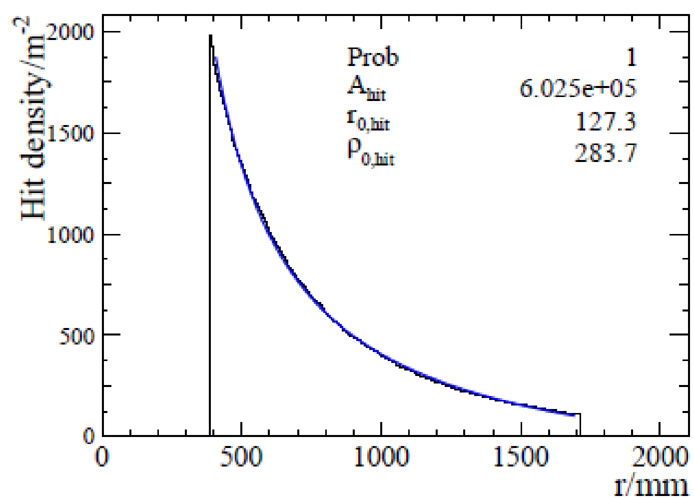
Manqi's talk

- Voxel occupancy
  - The number of voxels /signal
  - 9 thousand Z to qq events
  - 60 million hits are generated in sample
  - 4000-6000 hits/(Z to qq) in TPC volume
  - Average hit density: 6 hits/mm^2
  - Peak value of hit density: 6 times
  - Voxel size: 1mm × 6mm × 2mm
  - 1.33 × 10^{14} number of voxels/s @DAQ/40MHz
  - Average voxel occupancy: 1.33 × 10^{-8}
  - Voxel occupancy at TPC inner most layer: ~2 × 10^{-7}
  - Voxel occupancy at TPC inner inner most layer : ~2 × 10^{-5} @FCCee benchmark luminosity

The voxel occupancy takes its maximal value between 2 × 10^{-5} to 2 × 10^{-7}, which is safety for the Z pole operation.

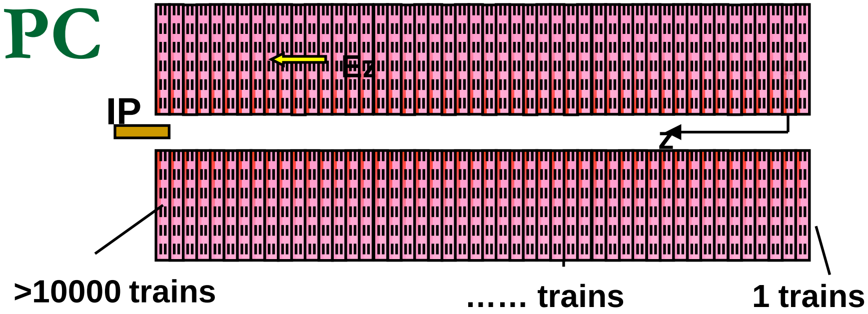


Hit map on X-Y plan for Z to qq events



Hit density as a function of radius

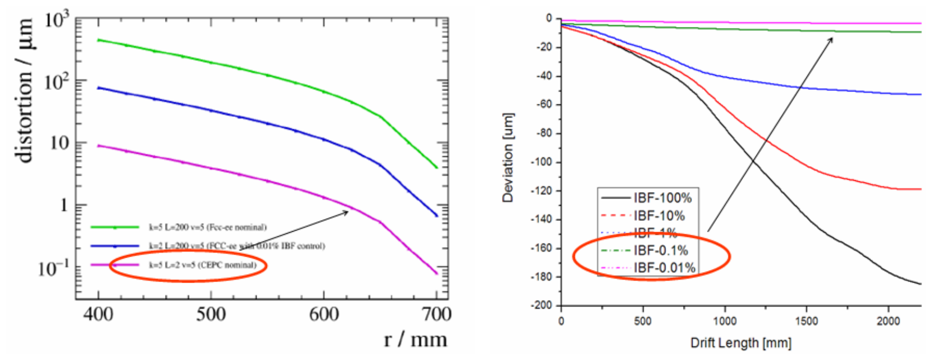
Technical challenges at CEPC



Amplification ions @CEPC

Ion Back Flow and Distortion :

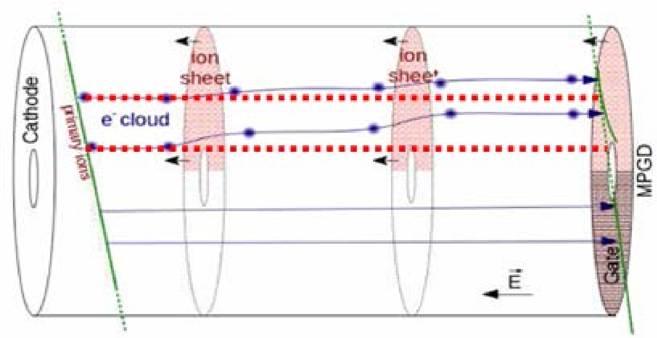
- ~100 μm position resolution in rφ
- Distortions by the primary ions at CEPC are negligible
- More than 10000 discs co-exist and distorted the path of the seed electrons
- The ions have to be cleared during the ~us period continuously
- Continuous device for the ions
- Long working time



Evaluation of track distortions

Calibration and alignment:

- Systematics precision (<20 μm internal)
- Geometry and mechanic of chamber
- Modules and readout pads
- Track distortions due to space charge effects of positive ions

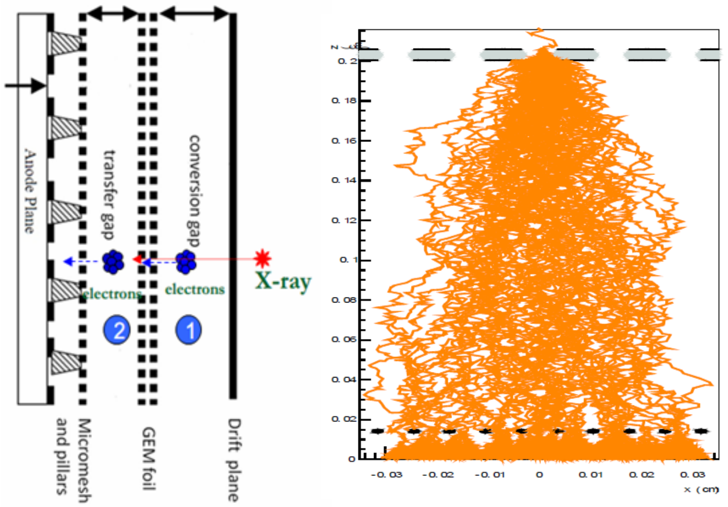


Ions backflow in drift volume for distortion

Options of technical solution

Continuous IBF module:

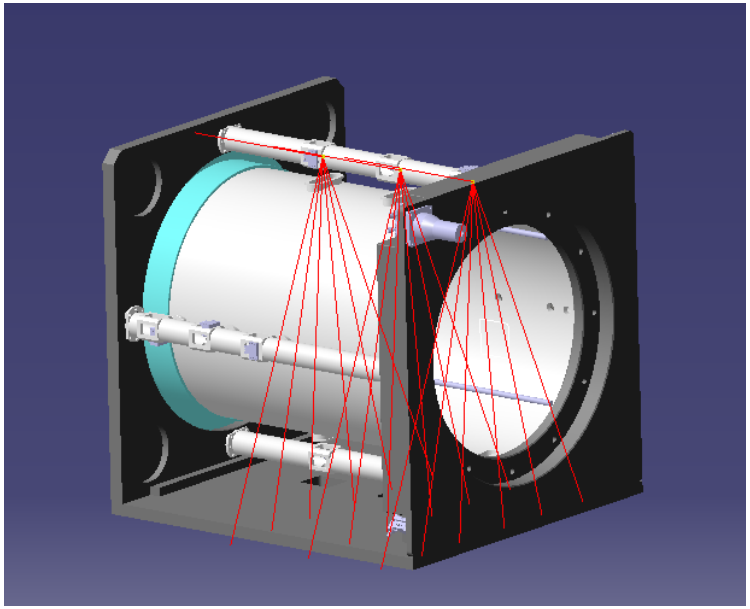
- Gating device may be used for Higgs run
- Open and close time of gating device for ions: ~ μs-ms
- No Gating device option for Z-pole run
- Continuous Ion Back Flow due to the continuous beam structure
- Low discharge and spark possibility



Continuous IBF module

Laser calibration system:

- Laser calibration system for Z-pole run
- The ionization in the gas volume along the laser path occurs via two photon absorption by organic impurities
- Calibrated drift velocity, gain uniformity, ions back in chamber
- Calibration of the distortion
- Nd:YAG laser device@266nm



TPC prototype integrated with laser system

Further R&D

Continuous IBF module for CEPC:

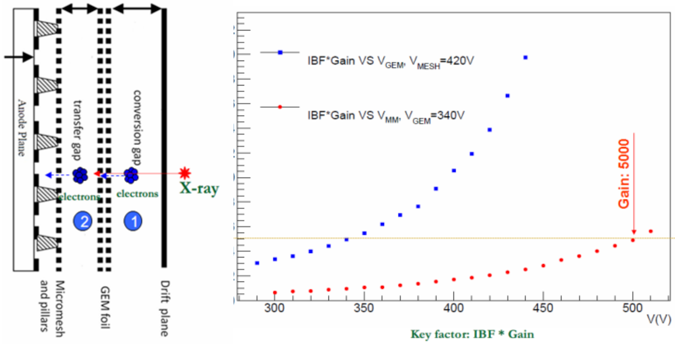
- No Gating device options used for Higgs/Z pole run
- Continuous Ion Back Flow due to the continuous beam structure (Developed in IHEP)
- ~100 μm position resolution in rφ
- Key factor: IBF×Gain=5 and leas than (R&D)
- Low discharge and spark possibility

Prototype with laser calibration for CEPC :

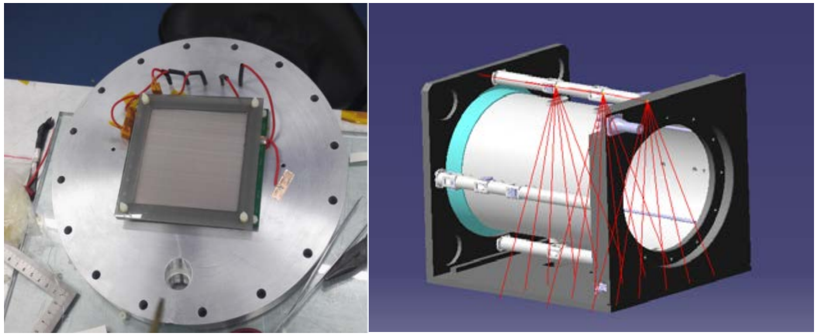
- Laser calibration system integrated UV lamp
- Calibrated drift velocity, gain uniformity, ions back in chamber
- Prototype has been designed with laser (Developed in IHEP and Tsinghua)_
- Nd:YAG laser device@266nm, 42 separated laser beam along 510mm drift length

Collaboration:

- Signed MOA with LCTPC international collaboration on 14, Dec., 2016
- New design detector collaborated with KEK and CEA-Saclay

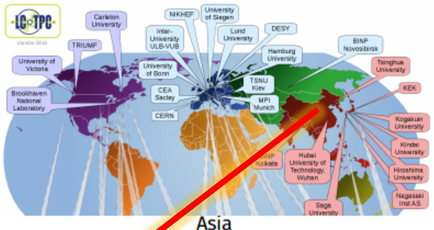


Continuous IBF prototype and IBF×Gain


TPC prototype integrated with laser system

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.

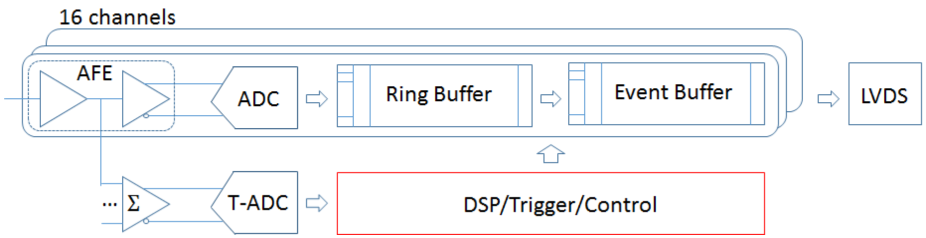


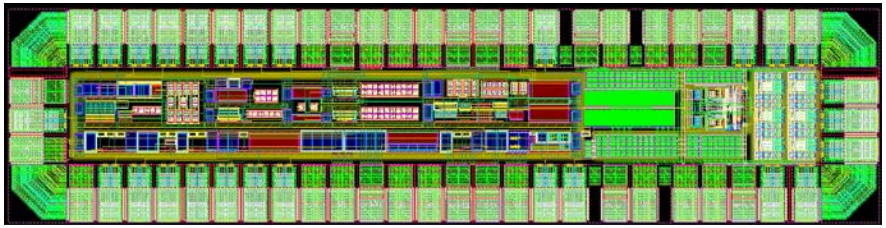
Institute	Collaboration Board Member
Institute of High Energy Physics, CAS	Huirong Qi

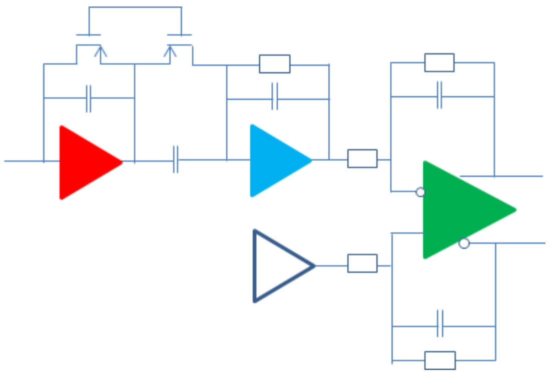
Joint LCTPC international collaboration

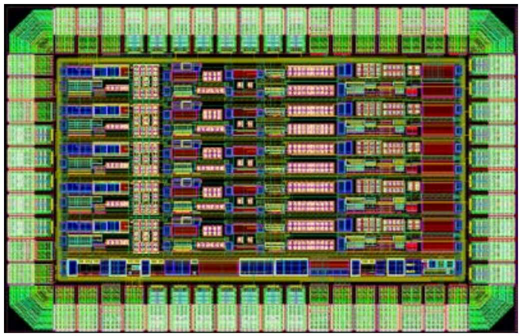
Low Power TPC Readout ASIC in 65nm

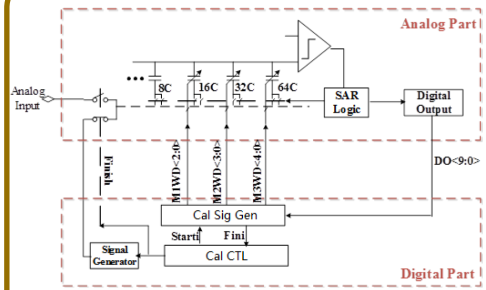
Deng Zhi, Tsinghua

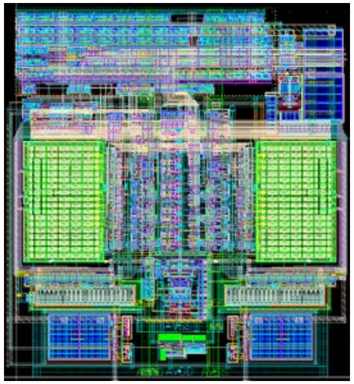


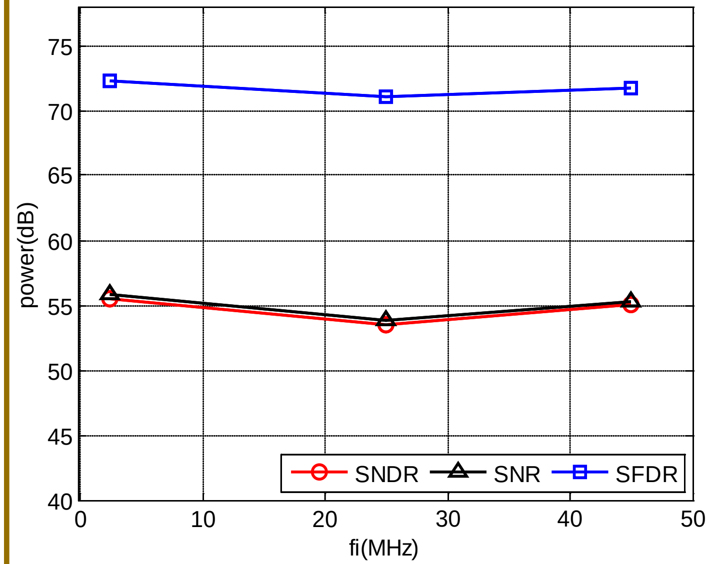












0.7mW @ 100MSPS, ENOB=8.8bit