Studies for a Silicon Telescope to extend the magnet facility at the DESY test beam.

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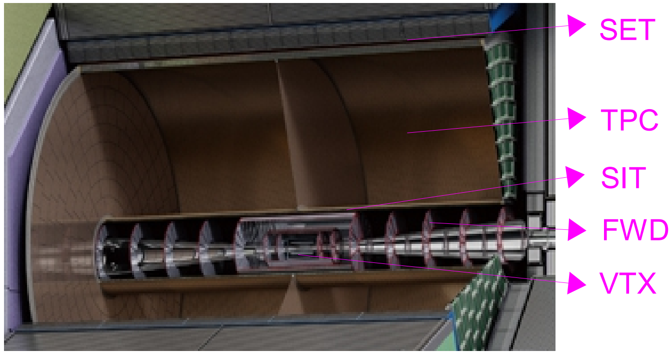
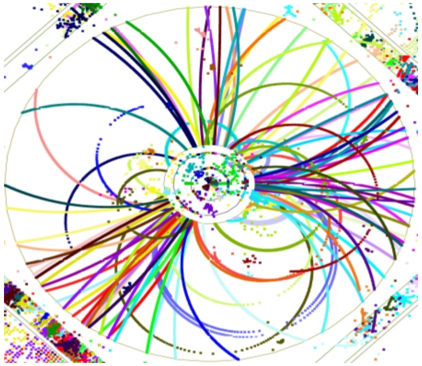
HELMHOLTZ ASSOCIATION AIDA 2020 LCTPC ilc DESY

International Large Detector – Tracking Requirements

- The ILD is one detector concept for the International Linear Collider
- The ILC is an e+e- accelerator up to centre of mass energies of 1TeV





tTh event

- Momentum resolution:
  - $\sigma(\Delta p_T/p_T^2) = 2\cdot10^{-5}$ GeV^{-1} (an order of magnitude better than ATLAS/CMS)
  - TPC alone: 10^{-4} GeV^{-1}

    200 space points → point resolution better than 100 µm
- Particle Flow
  - Low material budget (barrel TPC 5% X_0)
  - close to 100% tracking efficiency down to low momenta
- Full angular coverage and high hermeticity

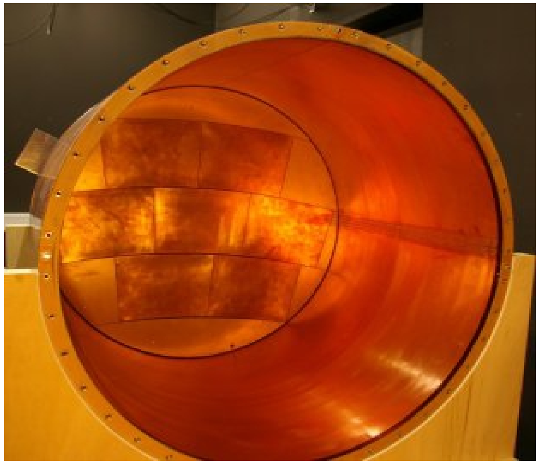
Large Prototype TPC and Current Infrastructure

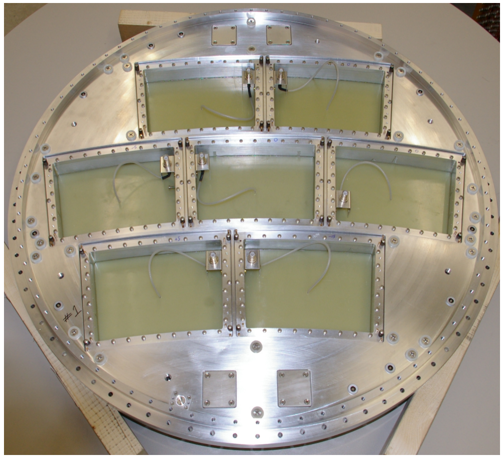
- Test beam area T24/1 at DESY (1-6 GeV e^- beams)
- Large Prototype TPC built and installed

- Infrastructure includes a large bore 1T magnet
  - 20% X_0 material budget

- LP field cage parameters:
  - Length: 61 cm, Diameter: 72 cm
  - Wall material budget: 1.3% X_0

- The endplate is able to host 7 readout modules (dimensions ~22x17 cm^2)



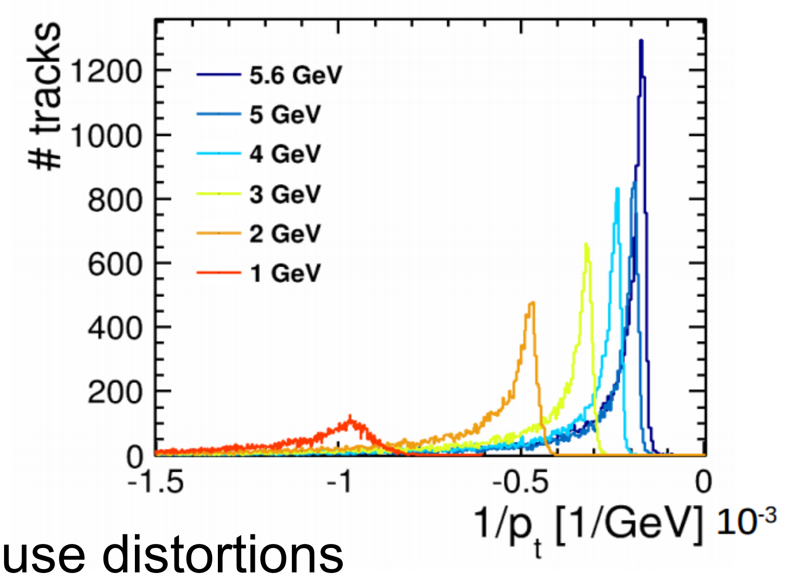


Mometum resolution measurement

- Determination of the momentum resolution in a tracking detector (Gluckstern formula)

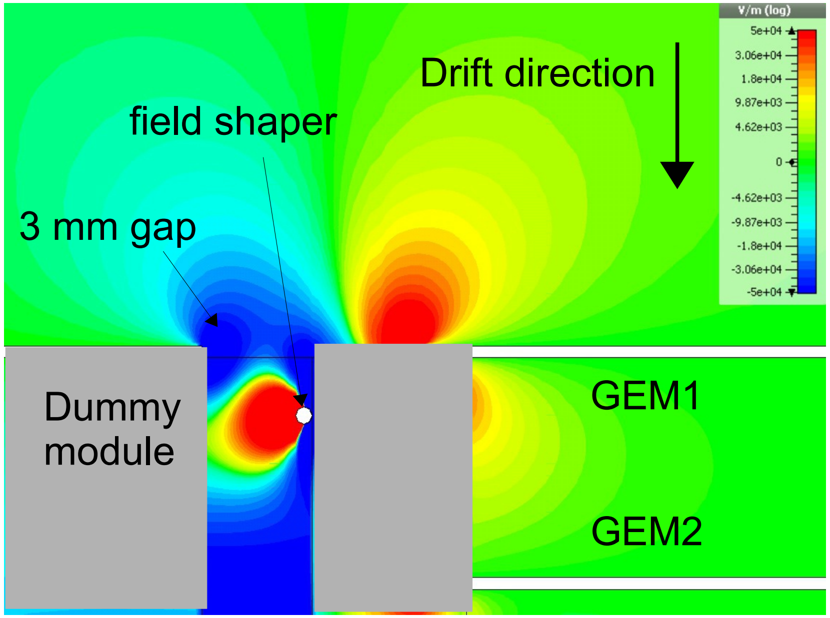
$$\sigma_{p_T} = \sqrt{\frac{720}{n+4}} \frac{\sigma \cdot p_T^2}{0.3\, B\, L^2}$$

- In the Large Prototype TPC case, there is a broad energy spectra due to the energy loss in the magnet



- In addition, field inhomogenities can cause distortions
- → Hits appear to be displaced
- → This has an impact on the momentum determination

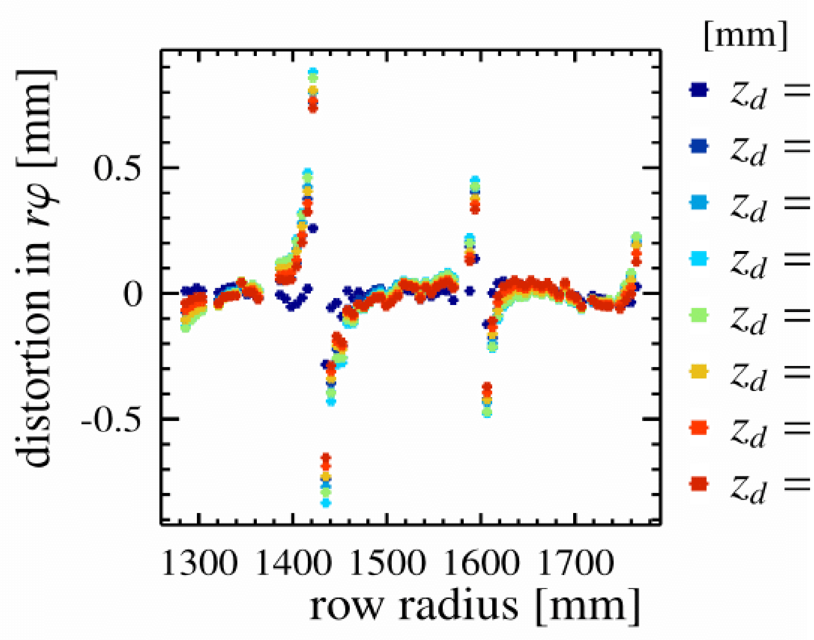
Field distortions in TPC



- Inhomogenities in Electric fields can cause distortions
- Magnetic field parallel to the electric field
  - ExB terms pronounced at module edges

Distortions in TPC tracks

- Test beam data
- E and B (1 T) fields present

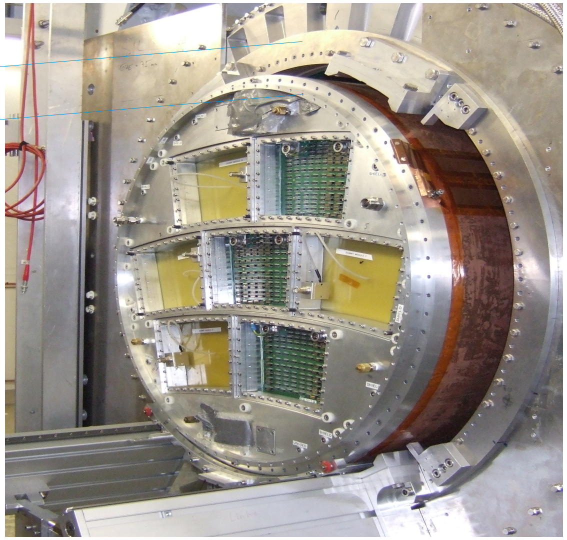


- A curved fit (helix) is used for the track → distortions can be partially absorbed in the track curvature

External Si tracker for Large Prototype TPC

- Solution: Build an external Si tracker (Si telescope) to provide reference tracks (entry and exit hits)

- Prototype for ILD TPC exists at DESY
- Goal: Combined test beam with LPTPC → track reference, field distortion corrections, momentum resolution measurements
- The Silicon tracker should be versatile and simple to be used as a telescope by other groups during test beams

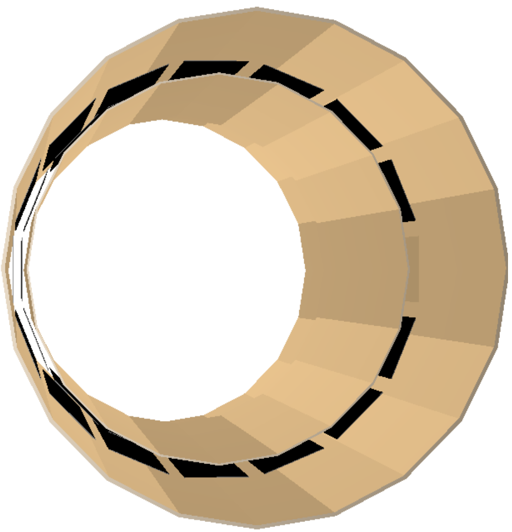


- Challenge: The Silicon system needs to fit in the existing infrastructure (available space is ~3.5 cm)

The Silicon Tracker Project

> Simulation studies to determine the general characteristics of the system

- Number of Silicon layers
- Distance between the Si layers
- Material budget
- possible dimensions of support structure
- optimal coverage area



> Hardware options

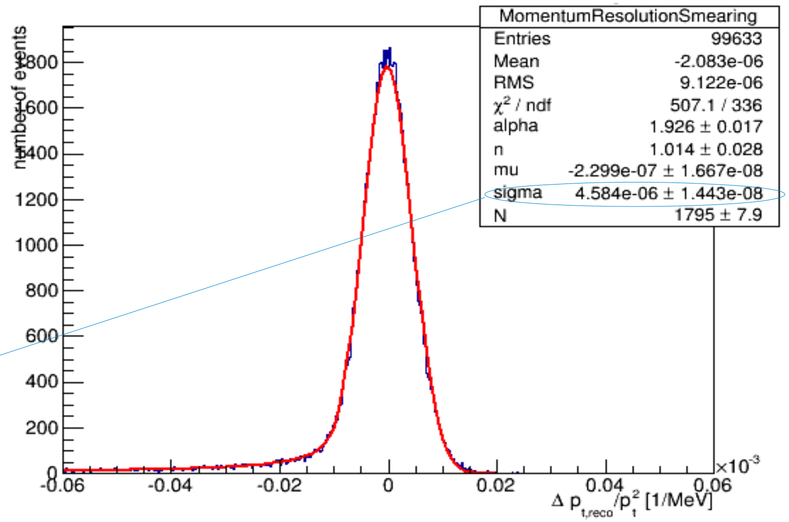
- Investigate hardware options to use in terms of sensors (pixels vs strips), chip, DAQ
- The DAQ system will have to be merged with the current TPC one

> Design support for the Silicon tracker to fit in the current infrastructure

Simulation Studies

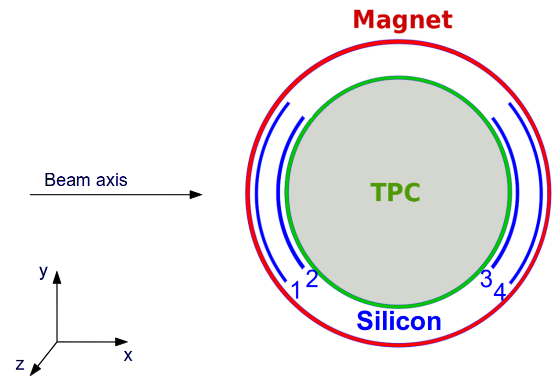
- Simulation Studies to determine the general characteristics of the system
- Geant4 simulation to include accurate model of the current material budget of the infrastructure
- For the Si system to be used as a reference, the Si standalone simulated momentum resolution should be better than the TPC one
  - → Criterion used to define the characteristics of the Si system
- Measuring the momentum resolution in standalone Silicon system and standalone TPC system by fitting a crystal ball function to the simulated points

Standalone TPC simulated momentum resolution is $4.58 \cdot 10^{-6}$ MeV^{-1}



Distance between Si layers

- Dependence of sensor spatial resolution on distance between layers
  - Momentum resolution shown in units of 10^{-6} MeV^{-1}



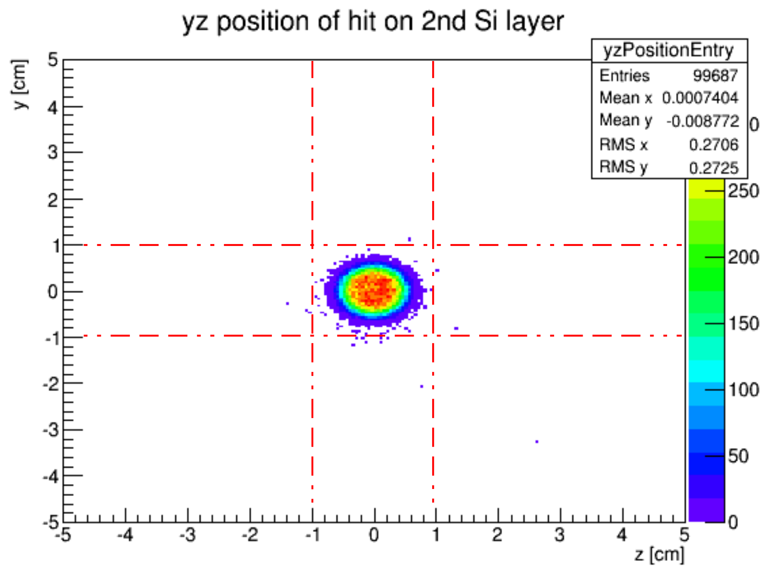
		Distance between inner and outer Si layer			
		4 cm	3 cm	2 cm	1 cm
Sensor spatial resolution	2.5 μm	2.85	2.90	3.00	3.68
	5 μm	3.05	3.21	3.63	5.52
	7.5 μm	3.37	3.65	4.43	7.92
	10 μm	3.68	4.16	5.33	9.90
	15 μm	4.49	5.36	7.53	14.3

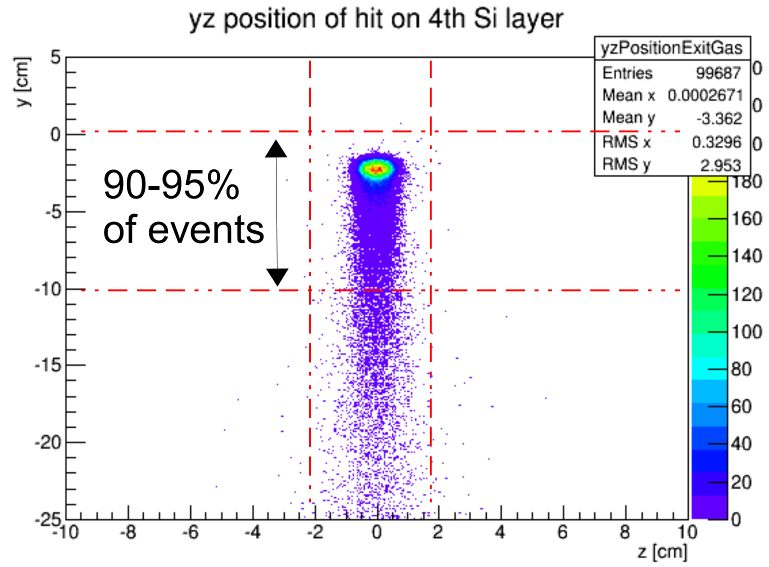
- Sensors with spatial resolution better than 10 μm are needed

ILC	ATLAS	CMS
<10 μm	12 μm (pixels)	10 μm (pixels)
	16 μm (strips)	20-30 μm (strips)

Coverage area

- Hit positions on front and back sensors for 5 GeV e^- beams

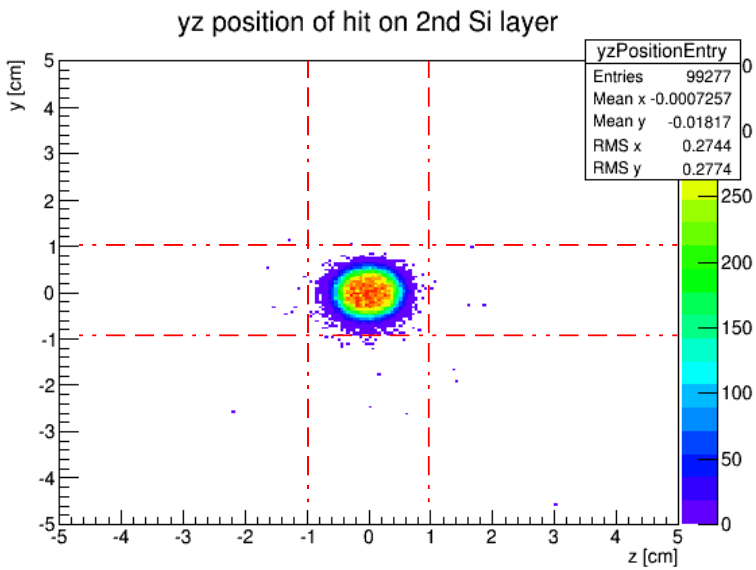


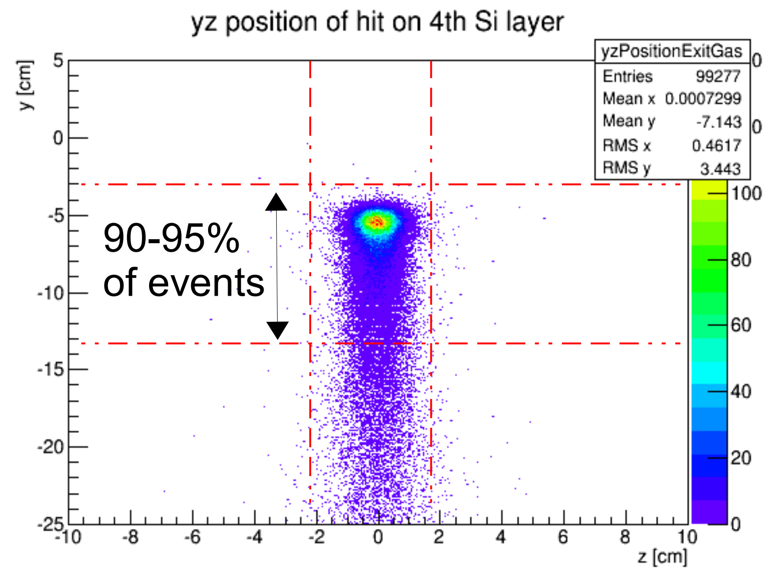


- For lower energy beams, the hit distribution on the back sensors is more spread and shifted to lower y values

Coverage area

- Hit positions on front and back sensors for 2 GeV e^- beams





- For lower energy beams, the hit distribution on the back sensors is more spread and shifted to lower y values
- Minimum coverage area: ~2x2 cm^2 for front and 4x10cm^2 for back sensors
- Larger coverage area is beneficial (e.g. for distortions, less moving and alignment of the system)

Hardware Options

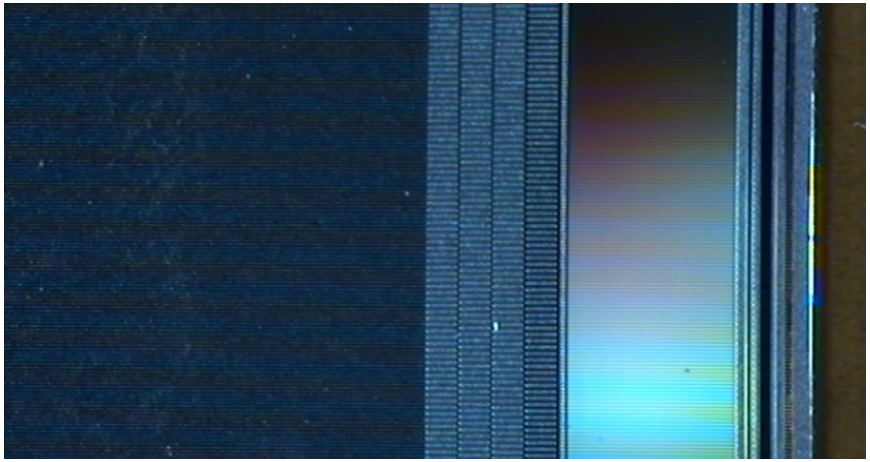
> Strip vs Pixel Silicon sensors

Strip sensors (SiD)

- Good spatial resolution (7-8 μm)
- Large sensor surface → Able to instrument large areas (eg 10x20 cm^2)
- Medium cost

Pixel sensors (Mimosa)

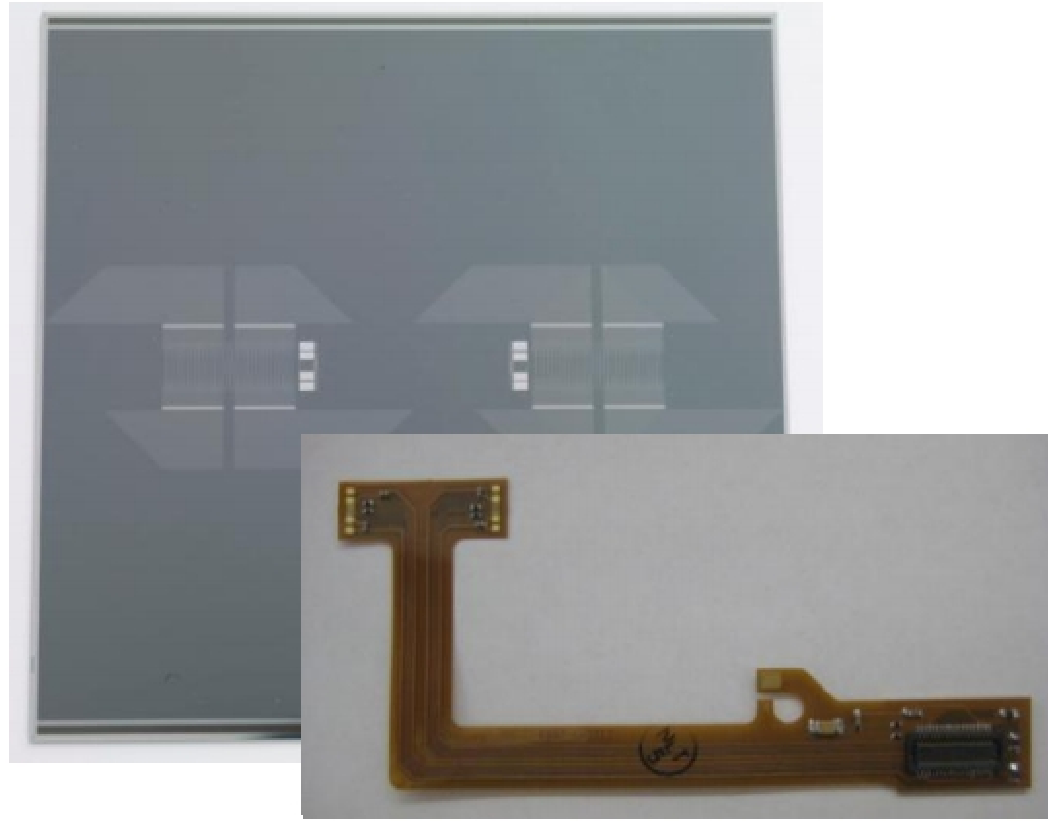
- Excellent spatial resolution (3-4 μm)
- Small sensor surface → Able to instrument minimum area only
- High cost



SiIC sensor
50 μm pitch

Hardware Options (2)

- Si strip sensors of 25 μm pitch → spatial resolution 7-8 μm
- Si sensor dimensions: ~10x10 cm^2
- Read out by two kpix chips bump bonded onto the sensor
- Control of sensor and kpix through wire bonding
- Capton cable to read out the data from kpix and control the kpix and sensor



Summary & Plans

- Instrumenting T24/1test beam setup with a Silicon telescope able to fit the requirements of the Large Prototype TPC

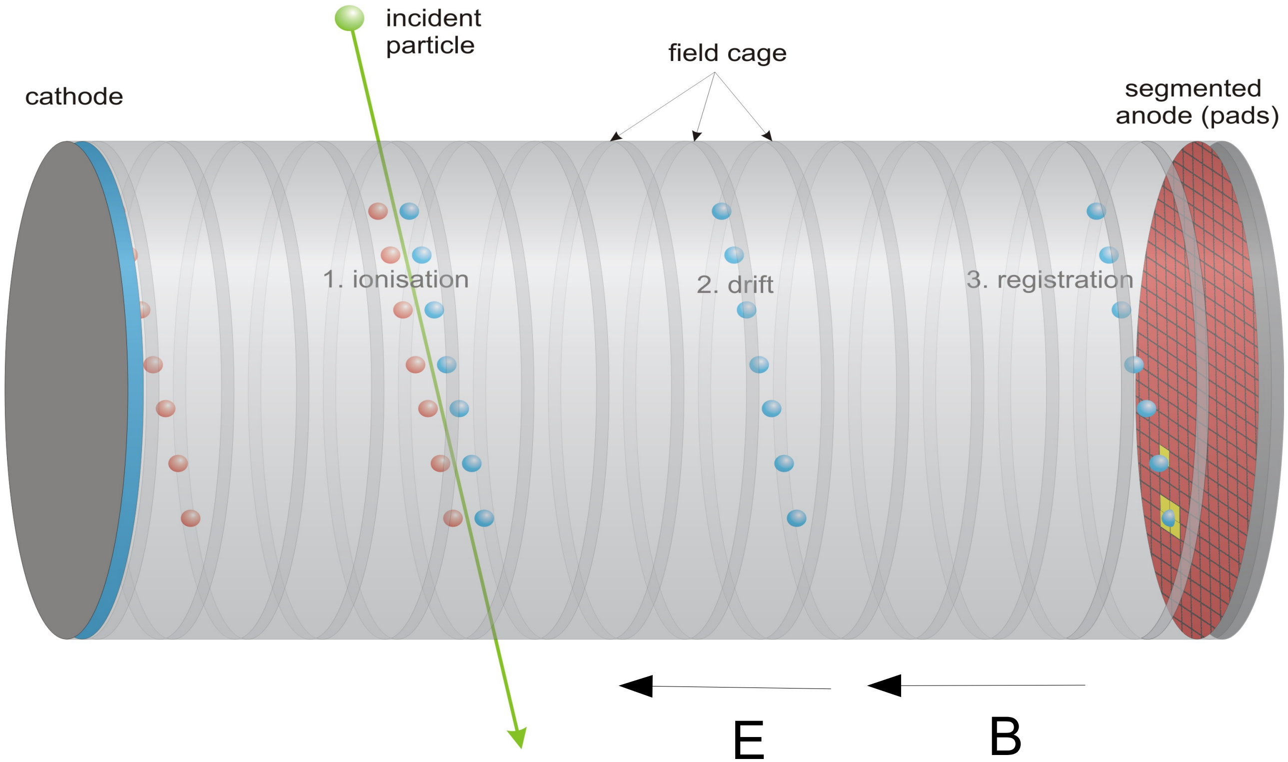
- Simulation studies to determine the characteristics of the Silicon system
- Sensors with spatial resolution better than 10 µm needed
- Large surface area desirable

- Plans to acquire hardware within the next months (1 month for ASIC, 3-4 months for sensors)

- Ongoing simulation studies within the ILC framework (DD4hep)
- Design process for Silicon system support

Back-Up

Time Projection Chamber – Working Principle



- Magnetic field parallel to the electric field
- Inhomogenities in Electric & Magnetic fields can cause distortions (ExB terms)