Towards a TPC for ILC

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Content

- Tracking Requirements
- TPC Advantages for Physics
- R&D: How to build a TPC
- Challenges for the TPC

TPC: Working Principle

- Very simple principle
- But: Projection over long distances (drift) requires highly controlled environment (gas compositon, temperature)

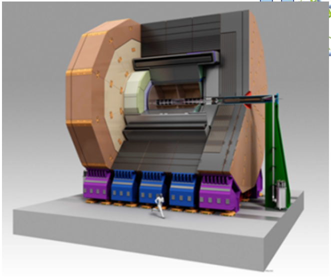
A TPC for ILD

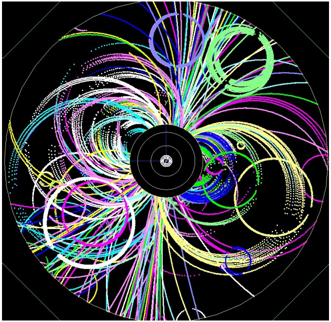
Requirements:

- **Tracking efficiency**
  close to 100% down to low momentum to fulfill Particle Flow Algorithm (PFA) requirements.
- **Minimum material**
  in front of the highly segmented calorimeter
- **Momentum resolution**
  $\sigma(1/p_t) = 2 \times 10^{-5}$ /GeV for Higgs mass measurement
  (TPC alone 10^{-4} /GeV)

Solution: TPC

- $\approx$ 200 continuous position measurements along each track
- Single point resolution of $\sigma_{r\phi} <$ 100 µm
- Lever arm of around 1.2 m in the magnetic field of 3.5–4 T





TPC Design Parameters

From the machine side:

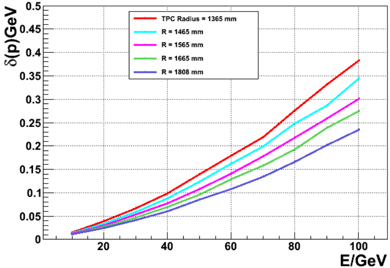
- Background:
  1. e^+e^- pairs: micro-curlers can be identified and removed
  2. mini jets: increase occupancy at low radius, not critical at ILC
- Beam structure:
  - Bunch train length: 1ms with bunches about 300 ns apart
  - TPC integration time: v_{drift}=70 mm/μs, L=2500 mm
    → read out time $t = 35\mu$s $>$ 100 bunches

From the detector side:

Outer parameters: radius, length, magnetic field
Glückstern formula:

$$\frac{\sigma(p_T)}{p_T} = \frac{\sigma(x)}{aBL^2}\sqrt{\frac{720}{N+4}}p_T$$

Large L → large radius → high cost



source: talk by YANG Ying

ILD Tracking Performance

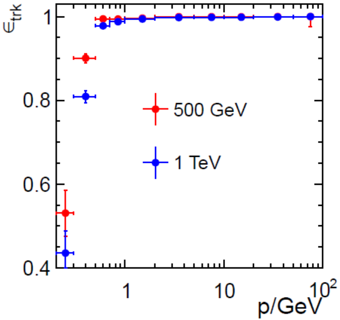
Simulation studies:

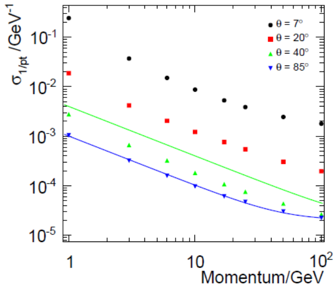
- Very good tracking efficiency
- Also in high multiplicity events
- Good momentum resolution

→ Tracking system with TPC can fulfill the requirements

Physics arguments for TPC:

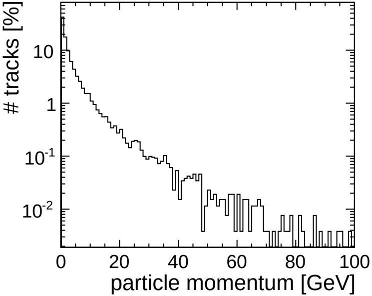
- Pattern recognition
  → kinks, long lived particles
- Tracking efficiency
  → down to low momenta
- Momentum resolution
  → mass peaks (e.g. Higgs recoil),
  → kinematic edges
  → branching ratios
  → determine $\sqrt{s}$
- dE/dx information



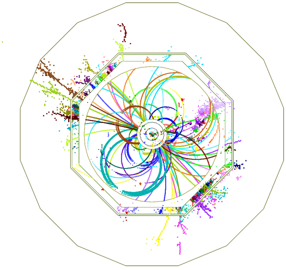


Low Momentum Tracks and Kinks

Zqqqq @ 500 GeV → 42% off tracks <1 GeV



$t\bar{t} \rightarrow 6q$ @ 500 GeV

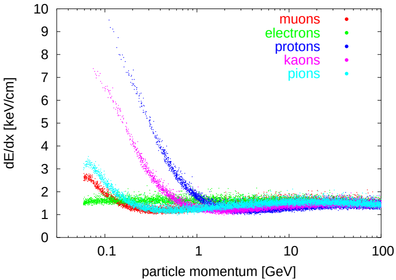


- BSM after LHC: small mass differences
→ soft tracks, exclusive decays
- SM: multi-jet final states: 6,8 or 10 jets
→ PFA performance limited by jet-finding
→ exclusive decay chain reconstruction

Reconstruction of kinks and non-pointing tracks:

- Improves vertex information
- Allows to study decay of resonances, e.g. Λ_b
- GMSB → up to 1m decay length

Particle ID with dE/dx



- dE/dx information not used in simulation or reconstruction and therefore not exploited in physics studies
- Mass information for track fit is important especially for low momenta where dE/dx is powerful

→ Find the right benchmarks to exploit dE/dx information

Examples from ALEPH:

- Identification of low momentum electrons, separation form other charged particles e.g. pions
- Identification of protons and anti-protons
- Identification of heavy charged particles

R&D: How to build a TPC for ILC

The concept:

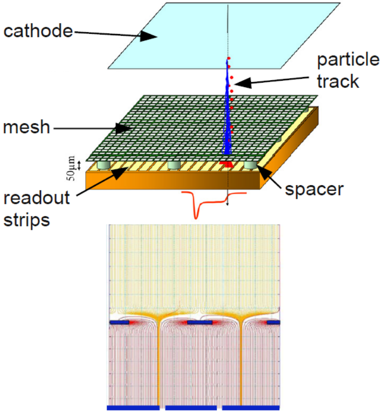
- How to reach the required momentum resolution?
  → excellent single point resolution
- Conventional amplification with wires not able to reach 100μm
- New technology: Micro-Pattern Gas Detectors

R&D needs to show:

- Proof of principle
- Technical feasibility
- Reach required resolution

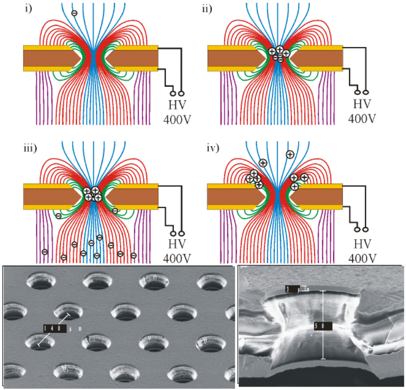
Micro-Pattern Gas Detectors

Micro-Mesh Gaseous Detectors



Y., Giomataris et al.,
Nucl. Instrum. Meth. A376:29-35,1996.

Gas Electron Multipliers



F. Sauli, Nucl. Instrum. Meth. A386:531-534,1997.

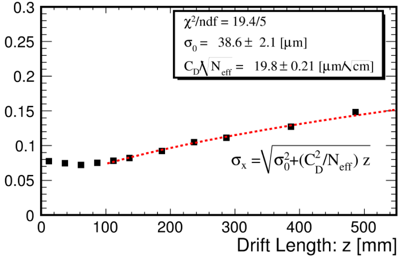
Results: Point Resolution

Different modules in Large Prototype

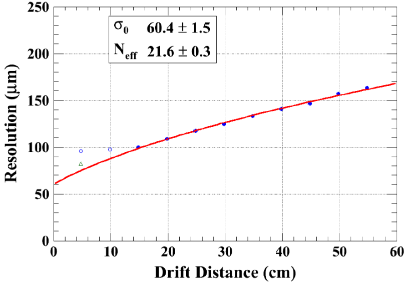
- B=1 T
- T2K Gas: $Ar(95\%)CF_4(3\%)iC_4H_{10}(2\%)$

All modules show similar results in agreement with requirements.

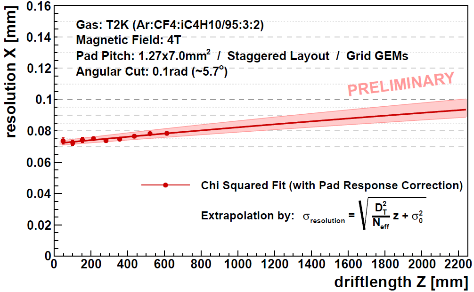
GEM module



MicroMegas, resistive anode



Small DESY prototype with B=4T



TPC Challenges

Status:

- MPGD technologies established
- First integration tests of modules in the LP successful
- Single point resolution obtained

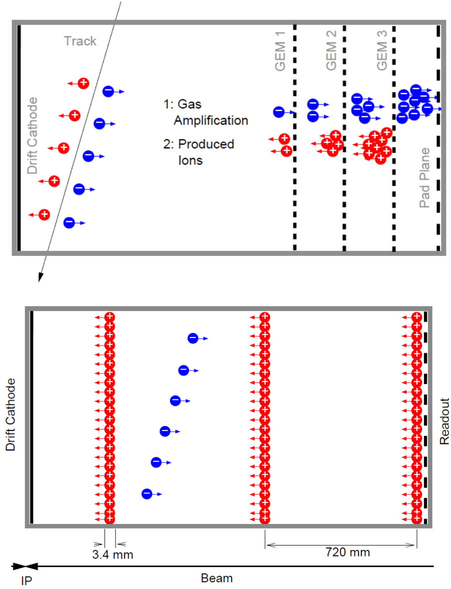
Things we still need to do:

- Long term stability and production of MPGD technologies
- Understand, minimize and correct field distortions
- Ion back flow
- Electronics development
- Environmental control
- Detector integration

My personal question:
Is the precision with which e.g. ALICE monitors and controls their TPC sufficient for high demands at ILC?

Ion Back Flow: Principle

- After each bunch train, a disk of positively charged ions from the amplification stage drifts back into the TPC volume
- Due to the very slow drift of ions up to three disks simultaneously in the gas volume of the ILD TPC → field distortions
- With adjusted GEM settings, the ion back flow can be minimized, but not to zero
- Gating possibilities: wires, mesh, special GEMs, ...?

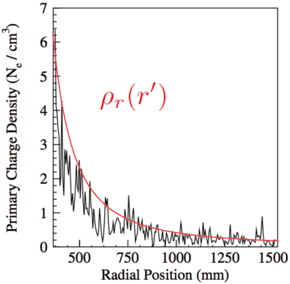


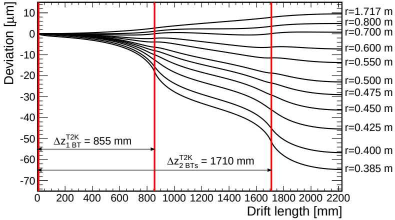
Ion Back Flow: Calculation

- The radial profile of the disk is dominated by machine-induced background during a bunch train
- Assumption: ion back flow factor from the amplification of 1 with respect to the primary ion charge
- Calculation of the expected distortion when electron passes through ion disk
  $\Rightarrow$ Maximum of $\approx 20\ \mu$m per disk
- Results in up to 60 μm distortion

$\Rightarrow$ **Gating needed**

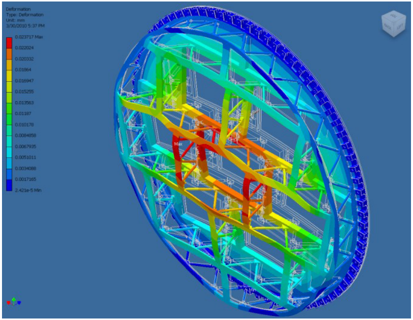
- Decide if wire, mesh or GEM gate
- Modules will be equipped with gates



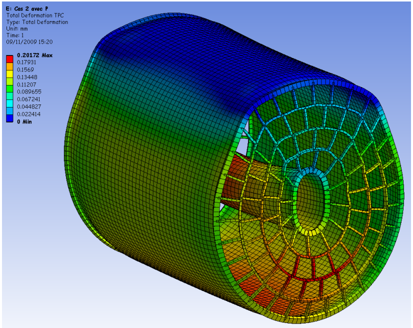


Mechanical Challenges

Endplate:
Material budget less than 25% X_0



TPC stability:
Integration of TPC in ILD



Outlook: Plans of LCTPC

The next few years:

Before entering the engineering design of an ILD TPC, the following issues need to be studied further:

1. Ion gate: the most urgent issue
2. Some issues with MPGD technologies and MPGD modules
3. Local distortions of MPGD modules
4. Demonstration of power pulsing
5. Cooling of readout electronics and temperature control of TPC
6. Performance of MPGD TPC in 3.5T magnetic field