Ion Back Flow with GEMs for ILC

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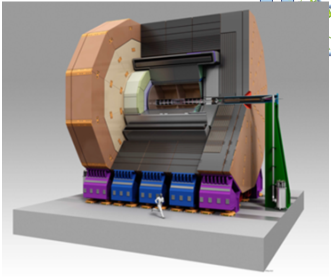
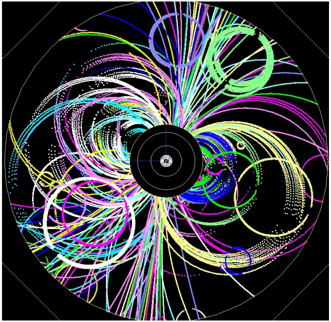
A TPC for ILD

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)

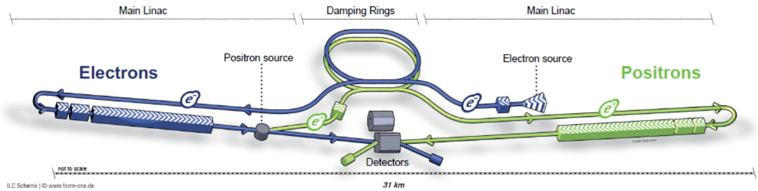


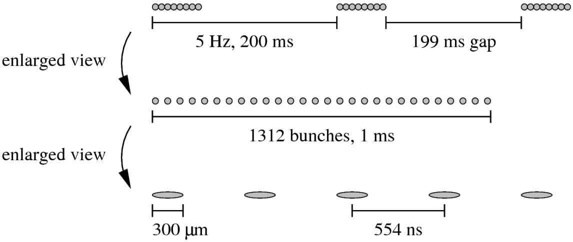


Solution: TPC

- $\approx$ 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

ILC Bunch Structure

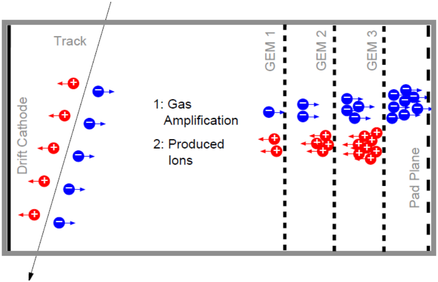


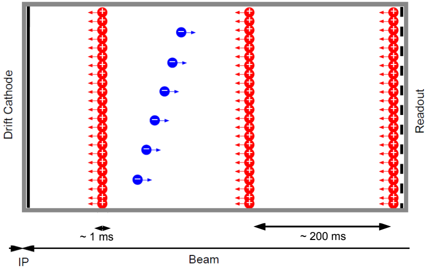


Ion Back Flow at ILC

@ ILC TPC:

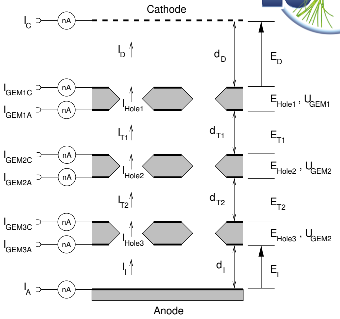
- After each bunch train, a disk of positively charged ions from the amplification stage drifts back into the TPC volume
- Due to the very slow drift of ions up to three disks simultaneously in the gas volume of the ILD TPC $\longrightarrow$ field distortions
- With adjusted GEM settings, the ion back flow can be minimized, but not to zero



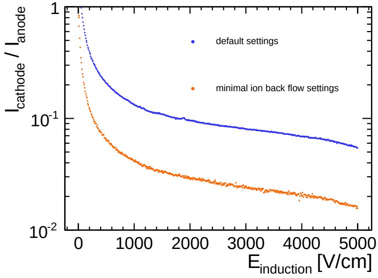


Measurements and Optimization

- Irradiation with Fe^{55} source (less than 100 MBq)
- Optimize the GEM setting for minimal ion back flow
- Systematic scan used to obtain parametrization



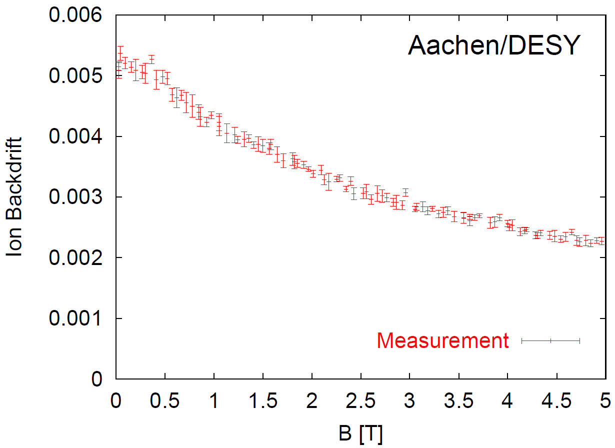
Ion Back Flow:



Value	Standard	ion back flow
E_D [V/cm]	250	250
U_{GEM1} [V]	250	230
E_{T1} [V/cm]	1500	2500
U_{GEM2} [V]	250	260
E_{T2} [V/cm]	1500	290
U_{GEM3} [V]	250	290
E_I [V/cm]	3000	4500

Both settings have the same gain ($\approx$ 5000).

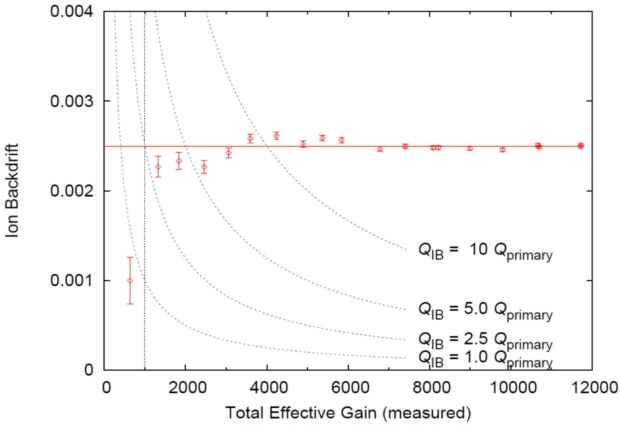
Influence of Magnetic Field



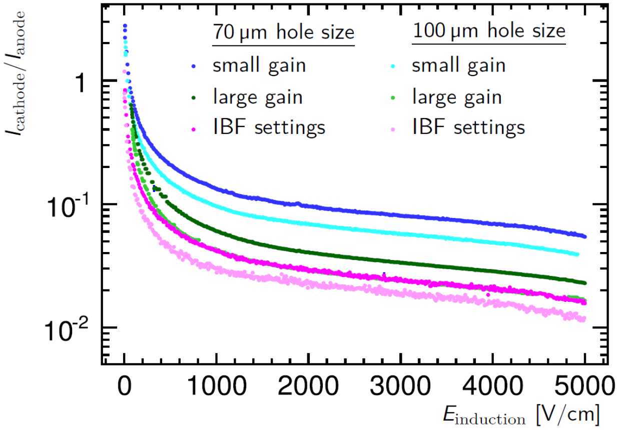
→ Ion back flow is reduced with increasing magnetic field due to improved electron extraction. This effect is much larger than the loss in collection efficiency.

Ion Back Flow vs Effective Gain

B=4T, TDR gas ($ArCH_4CO_2$ 93/5/2)



Influence of GEM Geometry



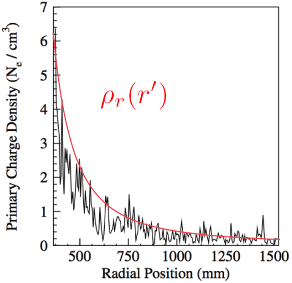
- Dark blue and pink line have the same gain
- Larger holes improve ion back flow
- GEM with larger holes is less stable, trip rate increases

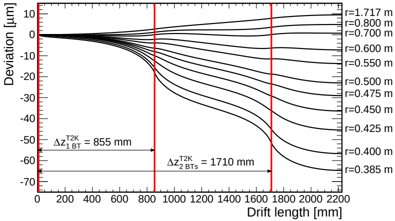
Ion Back Flow: Calculation

- 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
  ⇒ Maximum of ≈ 20 µm per disk
- Results in up to 60 µm distortion
- Same order as goal of 100 µm spatial resolution

⇒ **Conservative approach:**

- Gating is possible at ILC
- Remove each ion disk close to the readout between bunch trains
- Design a gating scheme





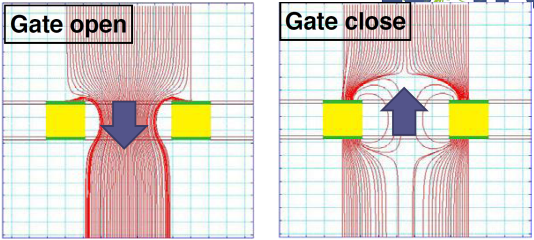
Ion Gate Options

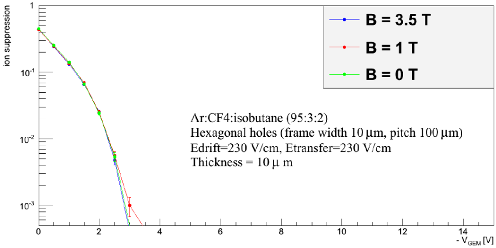
Prefered solution:

- Gate should be MPGD device
- Gate should be mounted on modules

GEMs as ion gate:

- high optical transparency of the gate is required to ensure its high transmission rate of the electrons in the open state
- low switching voltage of tenth of volts

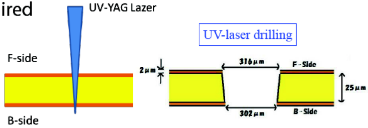




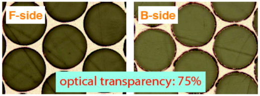
Simulation by P.Gross

Large Aperature GEM

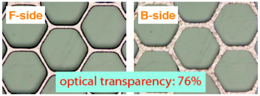
- **High optical transparency = Minimize rim width of GEM holes**
  - To achieve high electron transmission: 30 µm rim width & 330 µm pitch in honeycomb structure (= 85~90% optical transparency) required
- **R&D by D. Arai (Fujikura Ltd.)**
  - Thanks for his tremendous efforts!!!



- **Fujikura Gate-GEM Type 0 sample**
  - Round holes / UV- laser ablation technology (1 cm x 1 cm)
  - 15 µm (F-side) - 30 µm (B-side) rim width with PI thickness 25 µm: hard enough!



- **Fujikura Gate-GEM Type 2 sample**
  - Hexagonal holes / Ni-plating process (9 cm x 9 cm)
  - 30(F) - 40(B) µm rim width & 300 µm pitch with PI thickness 12.5 µm



These 2 samples: tested with a test chamber installed in a 1 Tesla solenoid magnet at KEK cryo center

- Fujikura Gate-GEM Type 4 sample (Ni-less process & 20(F) µm rim width) and RAYTECH samples (by using precise chemical etching technique) will be tested from 7 July at KEK cryo center

Slide by Katsumasa Ikematsu

Summary & Outlook

- Point resolution goal: 100 μm
- Triple GEM stack at 4T can reach ion back flow of 2.5 ‰
- Larger GEM holes reach further suppression of ion back flow, but are less stable
- BUT: ion back flow of 1 Q_{prim} creates up to 20 μm displacement per ion disk at ILC
- Prefered option for gating: MPDG device on the module
- Currently being studied: Large Aperature GEMs for high electron transparency