Cluster Counting - Prospects and Problems

- Status + Prospects
- Efficiency/Purity
- Systematics
- Particle Separation Power
- The Way to Go

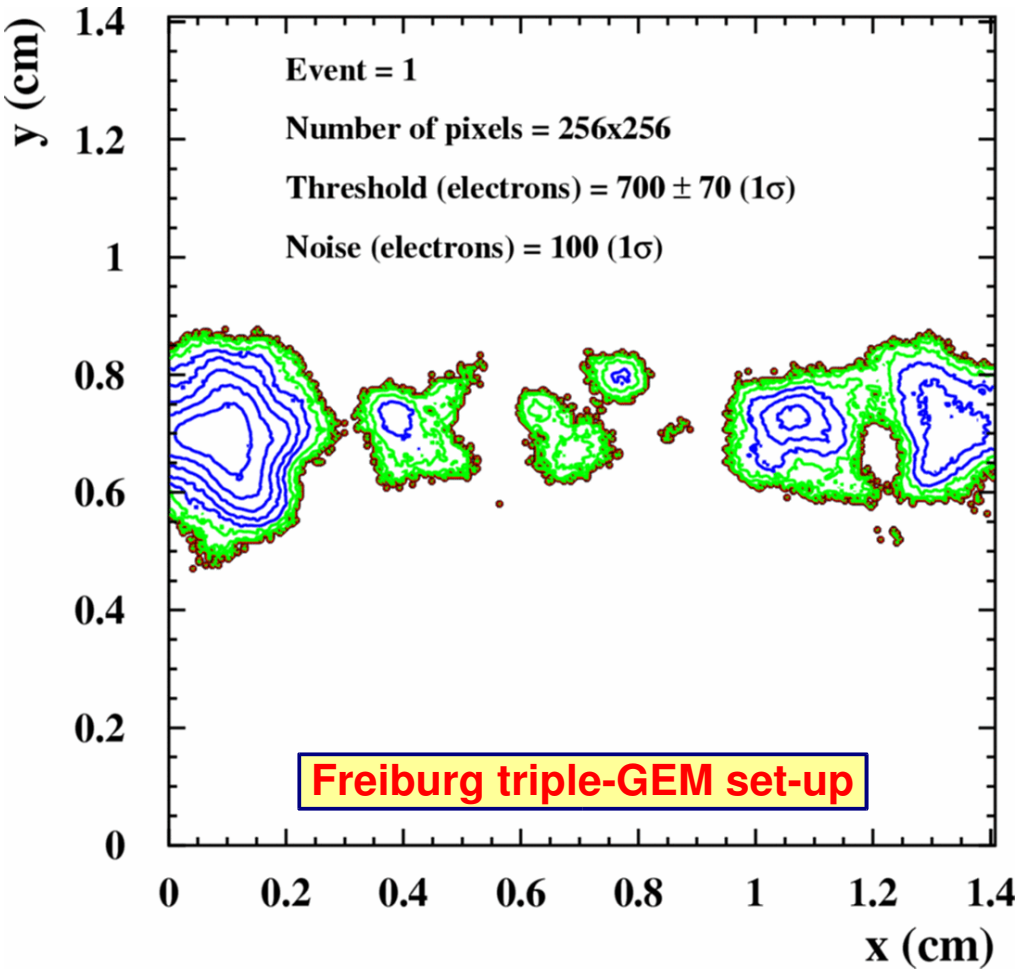
Present Status

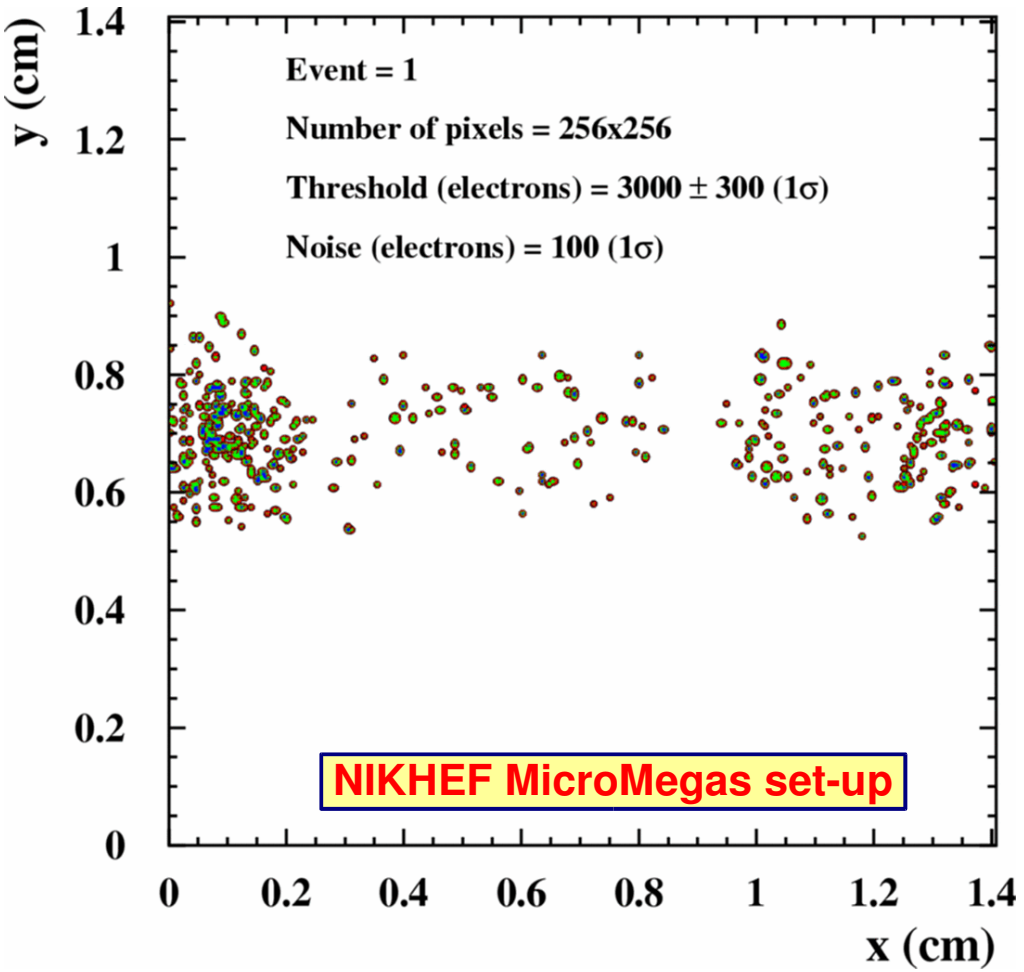
- **Both GEMs + MediPix and MicroMegas + MediPix set-ups have demonstrated feasibility of single electron detection**
- **GEMs**
  - **suffer from diffusion in between GEM foils**
    - **broadens distribution on MediPix, large blobs**
  - **need high total gas gain and low thresholds**
    - **limited sensitivity to single electrons, mainly sensitive to multi-electron clusters**
    - **cluster detection efficiency ~30%**
  - **rubust operation**
- **MicroMegas**
  - **low diffusion**
    - **small blobs**
  - **works with higher thresholds**
    - **efficiency for single electron detection ~90%**
  - **critical HV operation, so far limited lifetime of MediPix**

At the ILC?

- ...it might look like that...
  - 100 GeV muon, B = 4 T, TESLA-TDR gas, 100 cm drift

identical events: same generated primary clusters/electrons





Prospects

- **Expected dE/dx resolution for TESLA-TPC (TDR) ~4.3%**
  - classical charge measurement
  - optimal: 200-240 samples with 5-6 mm sampling width
  - 70% truncated mean
- **What can we expect from cluster counting?**
  - with 120 cm track length and ~30 clusters/cm
    -> ~3600 clusters and ~10000 electrons per track
  - number of clusters is Poisson distributed (that's nice!)
    - this is what we want to measure by cluster counting
  - number of electrons (including secondary electrons) is Landau distributed (that's bad!)
    - this is what we measure by classical charge measurement or by counting electrons
  - 3600 clusters -> 1.7% “dN/dx” error with perfect cluster counting
    - ~2.5 x better than by classical charge measurement
- **But what can be really achieved?**

Software

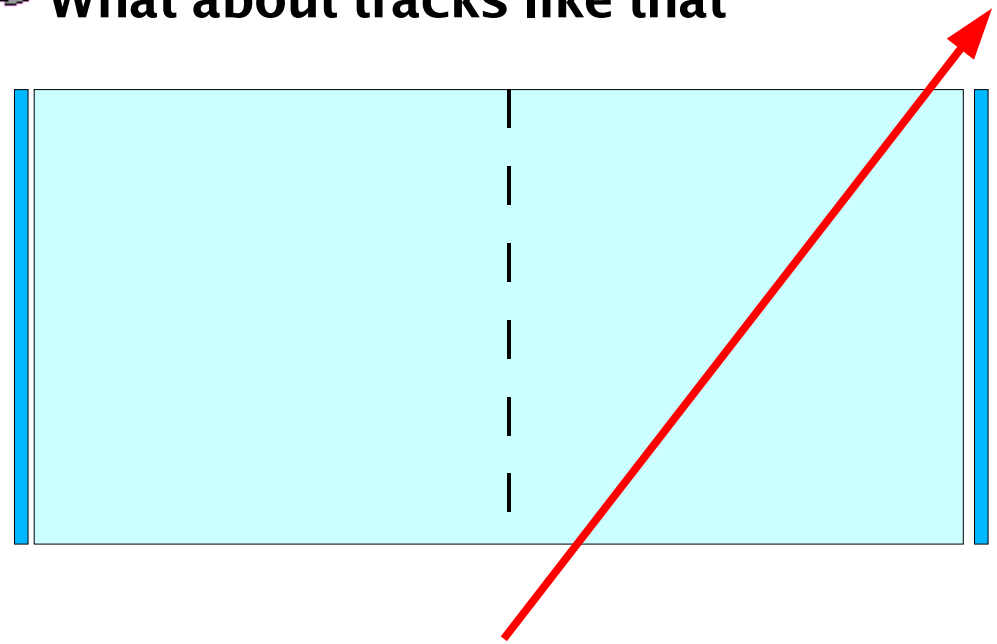
- MicroMegas can detect single electrons with high efficiency, GEMs can see ~clusters with lower efficiency (further optimizations might be possible)
  - hardware ~ok
  - what needs to be done to perform real cluster counting?
- SOFTWARE cluster finding algorithms are urgently needed!
  - MicroMegas
    - assign individual electrons to clusters
  - GEMs
    - resolve close-by clusters (blobs)
- Time information may help (when TimePix becomes available)
  - but probably longitudinal diffusion too large to provide useful information(?)

Efficiency and Purity

- GEM/MicroMegas + MediPix system for cluster counting will be not perfect
  - efficiency < 100%, not all clusters will be found/counted
  - purity < 100%, some mis-identification:
    multi-electron cluster counted as two or more individual clusters,
    two separate clusters counted as a single one
- Effect of lower efficiency can be estimated
  - 30% efficiency (100% purity)
    -> 3% dN/dx resolution (still a good number)
- Influence of limited purity less clear
  - mixture of Poisson and Landau distributions,
    statistically more difficult to predict

Systematics

- **Systematics could be the killer for cluster counting**
  - Number of detected clusters sesitive to MediPix threshold
    - GEMs has larger threshold dependence (because of lower threshold)
  - Stable, constant threshold probably managable
    - Can we keep threshold stable with time/temperature etc.?
  - Efficiency/purity depends on primary cluster density
    - what we want to measure!
  - What about tracks like that



small diffusion

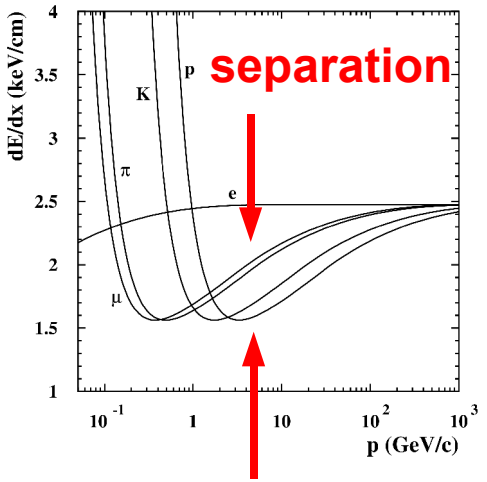
different efficiency and purity

large diffusion

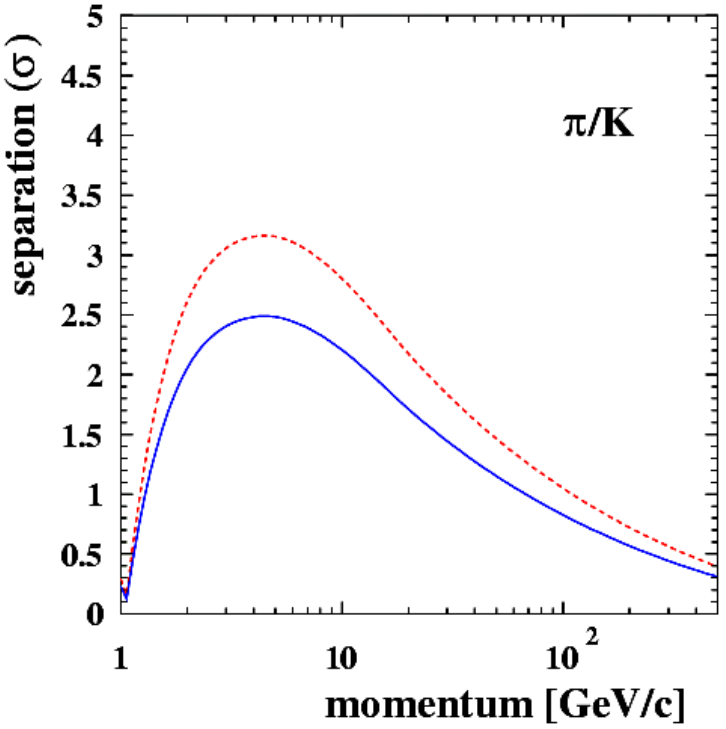
Particle Separation Power

- **After all, it's not the dE/dx resolution that counts but the Particle Separation Power**
  - **Separation of two particle species in dN/dx in units of the dN/dx resolution**

$$\text{separation power} = \frac{\text{separation}}{\text{resolution}}$$



from TESLA-TDR



this is the relevant plot for physics analysis

The Way to Go

- We need to make proof of principle for cluster counting
- Software
  - Develop clever cluster finding algorithms
    - requirements for GEMs and MicroMegas somewhat different
  - Detailed simulation (including delta-electron treatment) and performance study of longer tracks (120 cm) with GEM/MicroMegas + MediPix
- Hardware
  - GEMs
    - try to increase efficiency(sensitivity) -> reduce difusion
  - MicroMegas
    - improve operational stability
  - Test beam studies with sufficient MediPix to measure at least 15 – 20 cm long tracks
    - expected dN/dx resolution with perfect cluster counting ~ equivalent to dE/dx resolution with 120 cm long tracks