The jtpc Analysis Package

Dean Karlen
University of Victoria & TRIUMF

TPC R&D Workshop, LBNL, March 23-24, 2005

Outline

- Historical development
- jtpc packages
- The jtpc Track Fit
- Determining resolution
- Demonstration
- How to use it for your TPC prototype

History

- Development began in 2001 as a general purpose TPC simulation package
  - goal: to optimize TPC parameters for spatial resolution, by considering different pad geometries and gas properties

- Java chosen for its:
  - familiarity, popularity (especially with new students), portability, simplicity (wrt C++), extensive graphics, freely available IDEs (now netbeans) and histogramming/ntuple packages (JAS,JAIDA)

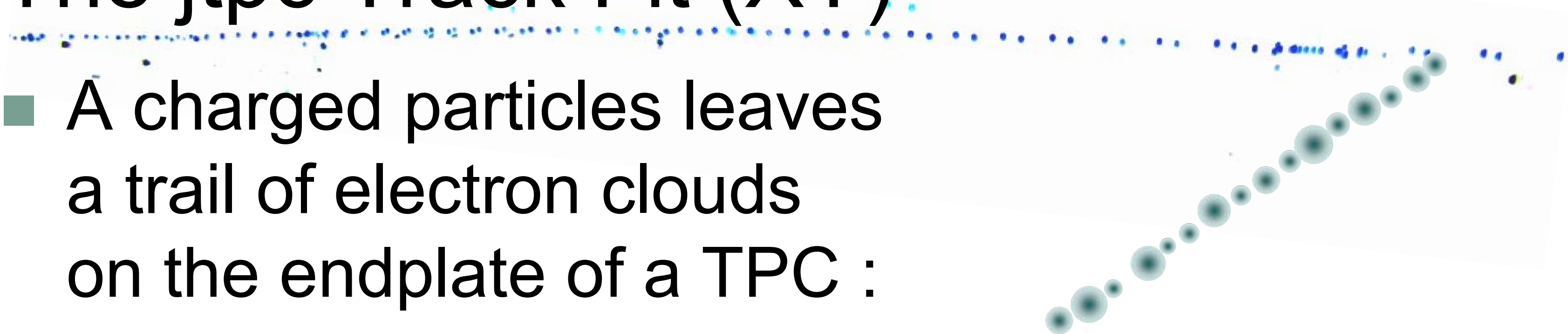
History (cont.)

- The simulation work eventually required an analysis framework… this was further developed to handle real data
  - the analysis code was translated to Fortran by Kirsten for the “Java challenged”
- Looking back – very satisfied with Java
  - quite easy to add new functionality
- Missing in Java: a standard numerical library and a robust native optimizer!

Main packages in jtpc

- tpcsimulator:
  - the core of the package, includes all classes that describe TPC components and the behaviours
- tpcdata:
  - a base class and extensions to access data
    - a large number of unique formats
- tpctracker:
  - track fitters in XY (likelihood) and YZ (chi-square)
- tpcanalyzer:
  - contains a base class to be extended by user
  - produces .aida ntuples
- tupleanalyzer:
  - contains several classes to analyze .aida ntuples

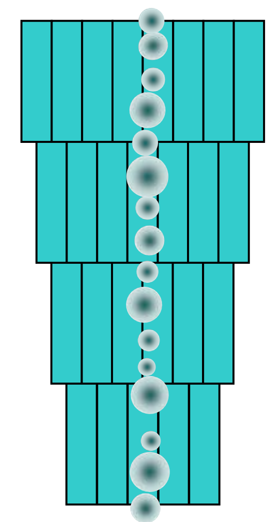
The jtpc Track Fit (XY)



- A charged particles leaves a trail of electron clouds on the endplate of a TPC :
- To describe this pattern completely, we would need:
  - track parameters to describe the path and
  - the locations and amplitudes of all of the clusters along the path
- With relatively large pads, we don't have enough information to determine the latter

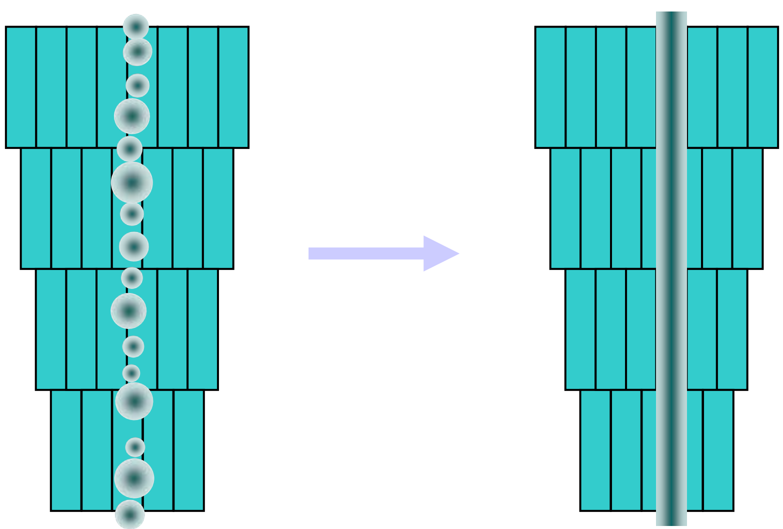
The jtpc Track Fit (XY)

- Good resolution is possible with large pads when there is a preferred track direction (like in a LC). By orienting the long sides of pads with the preferred track direction, the charge sharing pattern is
  - sensitive to the track parameters, but
  - relatively insensitive to the cluster locations and amplitudes along the path.



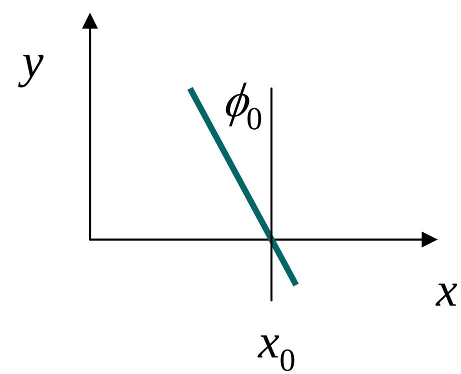
The jtpc Track Fit (XY)

- The likelihood of observing the charge sharing pattern is estimated by using a simplified model:
  - the ionization trail is approximated by a track with uniform longitudinal density and a Gaussian transverse profile



Track parameters:

$$x_0, \phi_0, \frac{1}{r}, \sigma$$

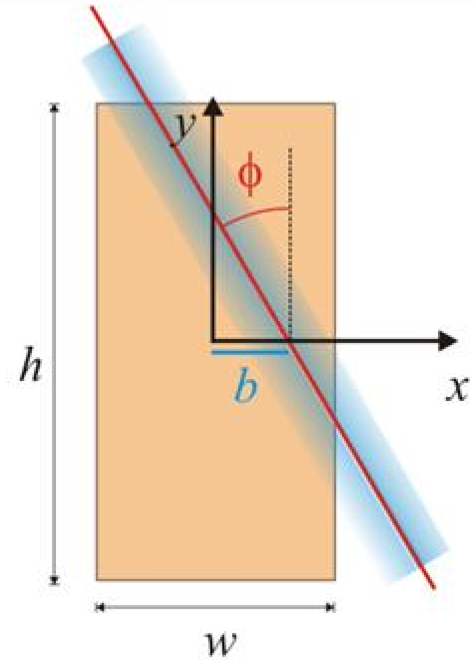


The jtpc Track Fit (XY)

- Likelihood calculation:
  - Given a set of track parameters, the expected charge in each pad along a row is calculated and normalized so that the sum in the row is 1

    $\rightarrow$ the probability for an electron to hit a particular pad in a row
  - The likelihood of the observed charge pattern within a row is calculated using a multinomial pdf, given the pad probabilities and the total primary ionization statistics sampled by the row
  - The overall likelihood is the product of all row likelihoods
- Likelihood maximized $\rightarrow$ track parameters

Detail: Integration of line Gaussian over pad



$$I(b,\phi,\sigma,h,w) = \int_{-w/2}^{w/2} dx \int_{-h/2}^{h/2} dy \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{[(x-b)\cos\phi + y\sin\phi]^2}{2\sigma^2}}$$
$$= \eta(b,\phi,\sigma,h,w) - \eta(b,\phi,\sigma,-h,w) + \eta(b,\phi,\sigma,-h,-w) - \eta(b,\phi,\sigma,h,-w)$$

$$\eta(b,\phi,\sigma,h,w) = \frac{1}{\cos\phi\sin\phi}\xi\left((b+\frac{w}{2})\cos\phi + \frac{h}{2}\sin\phi,\sigma\right)$$
$$\xi(u,\sigma) = \frac{u}{2}\mathrm{erf}\left(\frac{u}{\sqrt{2}\sigma}\right) + \frac{\sigma}{\sqrt{2\pi}}\exp\left(\frac{-u^2}{2\sigma^2}\right)$$

Determining resolution (XY)

- Since the jtpc track fit does not define points along the track, we cannot use point residuals to determine resolution
- Two track fit approach is used instead:
  - Fit data to define a reference track
  - Fix all track parameters except x_0 to reference track results and fit data from one row to determine x_0'
  - Standard deviation of residuals: σ
  - σ_w : reference track includes the row
  - σ_{wo} : reference track excludes the row
  - Row resolution: $\sigma_{row} = \mathrm{sqrt}(\sigma_{wo}\, \sigma_w)$

Determining resolution (XY)

- Geometric mean:
  - is exact for a Gaussian distributed points along a path
  - checked by:
    - Monte Carlo simulations – compared with residual from “truth” information
    - Laser tracks – compared with repeated measurements of laser tracks at same location
  - for both cases it is seen that resolution scales with $1/\sqrt{N_{row}}$
- It appears that the geometric mean resolution is valid for extrapolation and comparisons

Demonstration of jtpc data analysis

- Interactive use
  - view event displays
  - set analysis parameters
    - save parameter set
  - try out track fits
  - process a set of events → produce ntuple
- Batch use
  - specify tpc, data set(s), analysis parameters
- Ntuple analysis
  - JAS3, or
  - standalone analyzers

How to use jtpc for your TPC

- define TPC geometry
  - is done interactively using tpcsimulator
  - demonstration
- extend TpcData class
  - or use an existing one
- extend TpcAnalyzer (main class)
  - or use an existing one

- start the TpcAnalyzer

Demonstration of tpcsimulator

- Interactive use
  - build the TPC from TpcParts
  - add ionization (single clouds or tracks)
  - view event displays
  - try out track fit

- Batch use
  - specify tpc and run information

jtpc software

- The jtpc package source code is available from a CVS repository:
  - cvs -d :pserver:dryad@phys.uvic.ca:/home/cvsroot login
  - cvs checkout jtpc
- Some documentation:
  - http://www.linearcollider.ca:8080/lc/Members/karlen/jtpc
  - more complete documentation could be prepared if there is interest
- There is no intention to develop this into a package suitable for a large scale experiment
  - its purpose is to study resolution properties only
  - its methods and structure may be useful starting points for larger simulation/analysis packages

Summary

- jtpc is a useful tool to understand the performance of small TPC prototypes and to optimize parameters for new TPCs that use micropattern gas detectors