A Framework for TPC Simulation

Santa Cruz Linear Collider Retreat

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Motivation for this work

- Explore the parameter space for TPC design:
  - dimensions, gas, B field, gas amplification technology, pad designs
- Simulation must be anchored on reality:
  - compare with several prototype TPCs
  - understand signals
  - test out tracking ideas
- Not intended for use inside a LC detector simulation package for physics studies

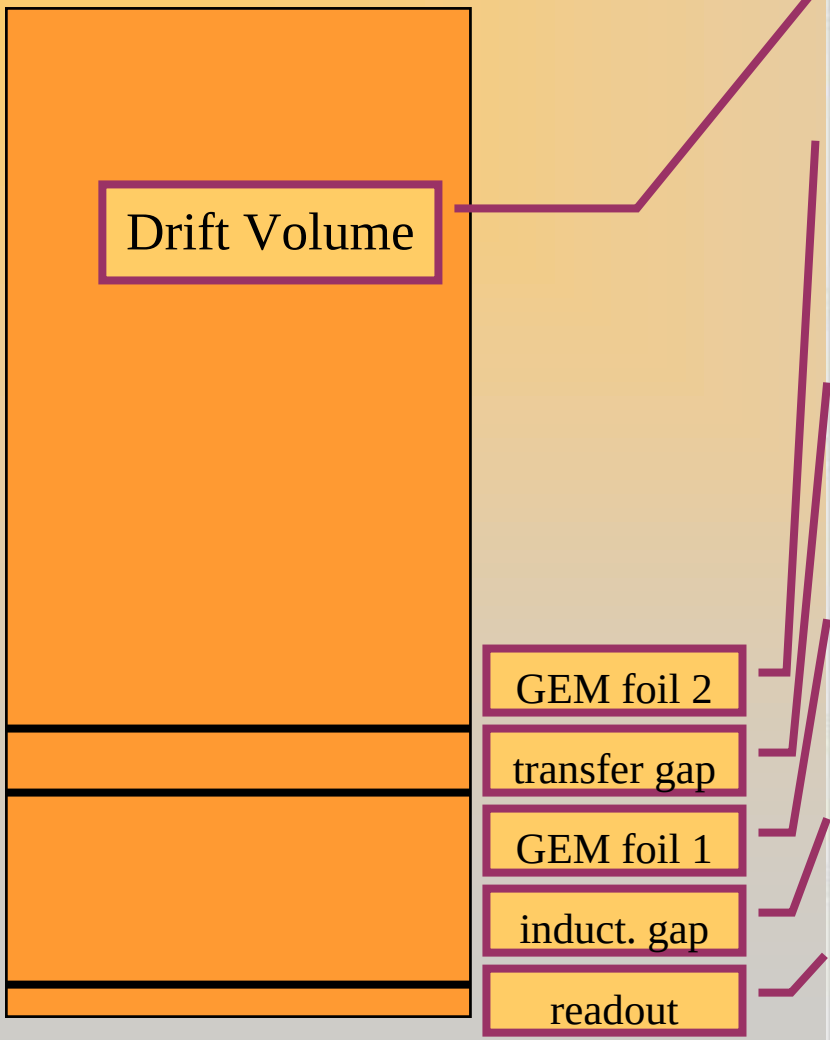
Requirements/Design

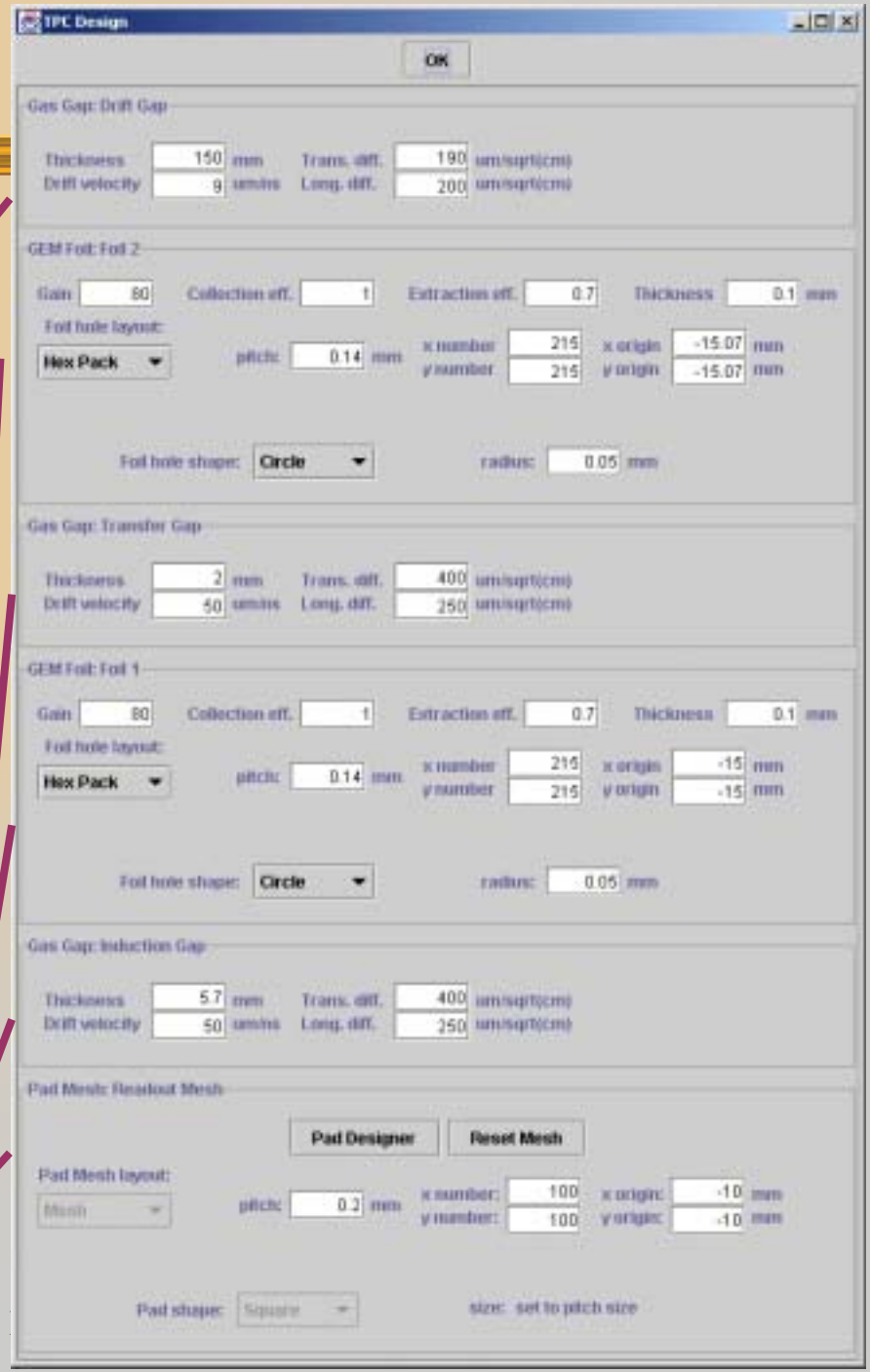
- Requirements
  - Easy to use (graphical interface)
  - Flexible enough to allow any TPC design
  - Easy to maintain / add additional features
  - Portable
- Design choices
  - Object oriented (Java)
  - Use JAS tools:
    - JAS Histogrammer
    - JAIDA

Building a TPC

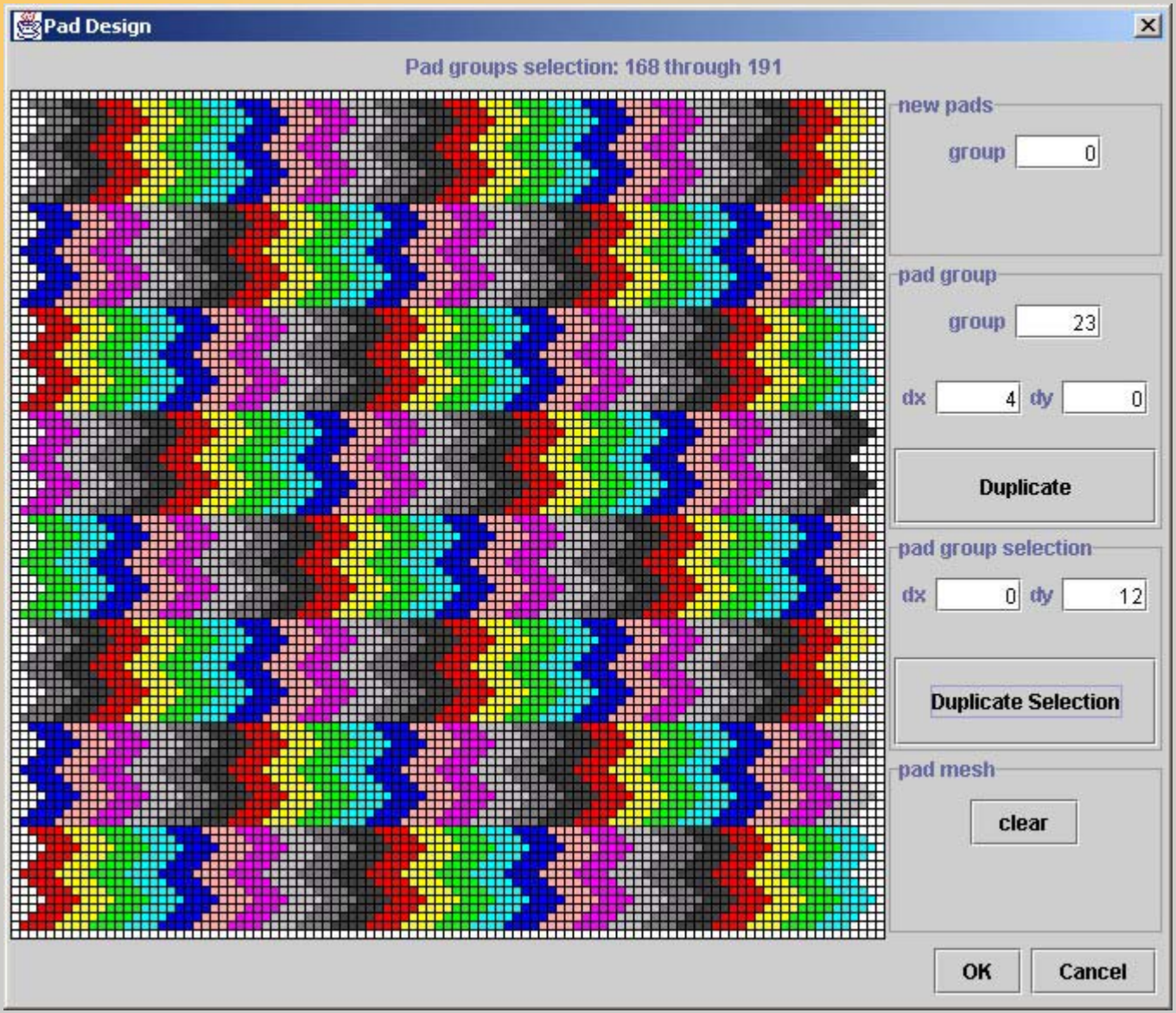
- The TPC is built from a set of TPC parts
  - gas volumes
  - GEM foil amplification stages
  - readout pad structures
- TPC parts have methods to transport electron clouds through them
- The parameters for each TPC part are accessible through a single design window

TPC design window

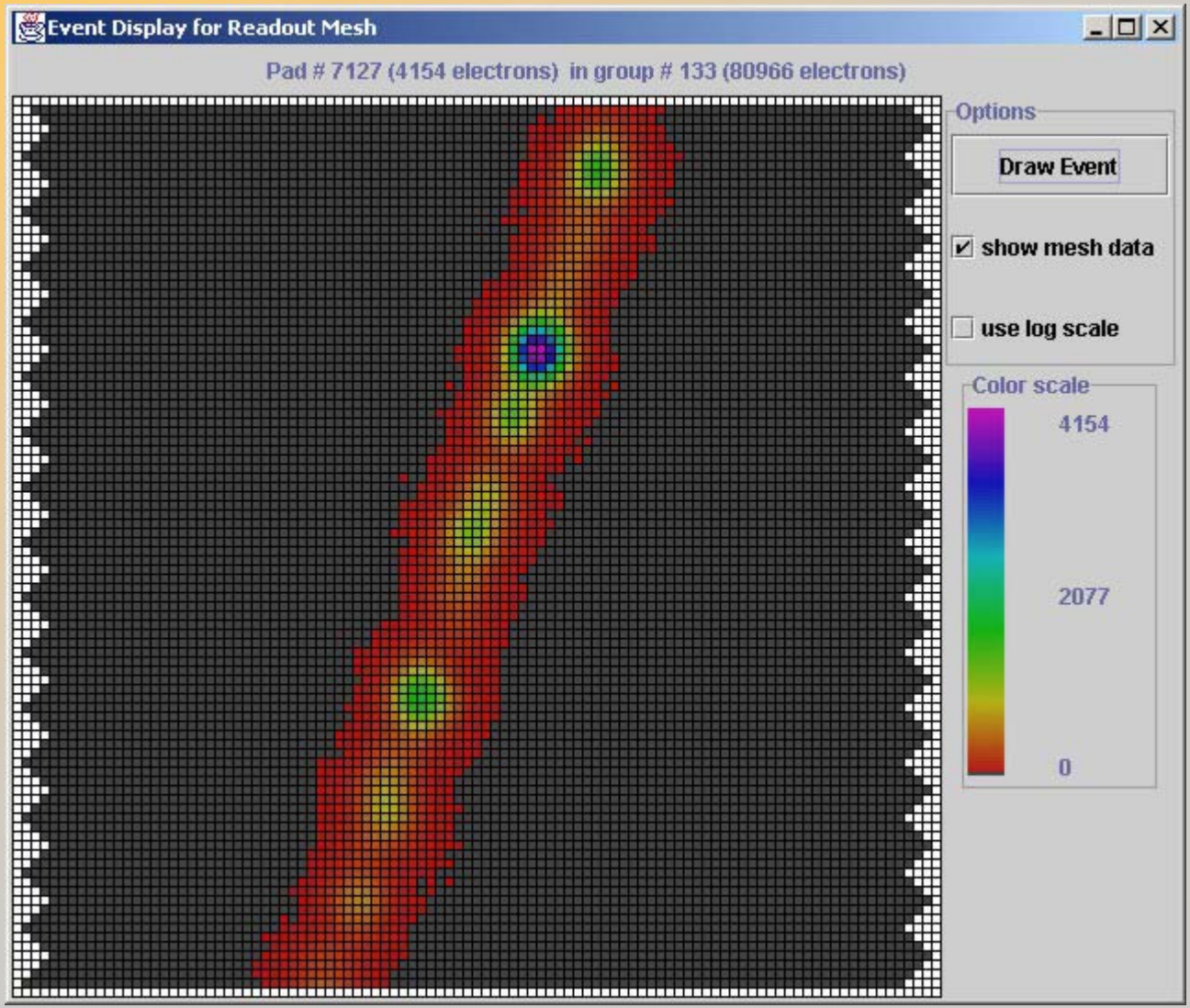




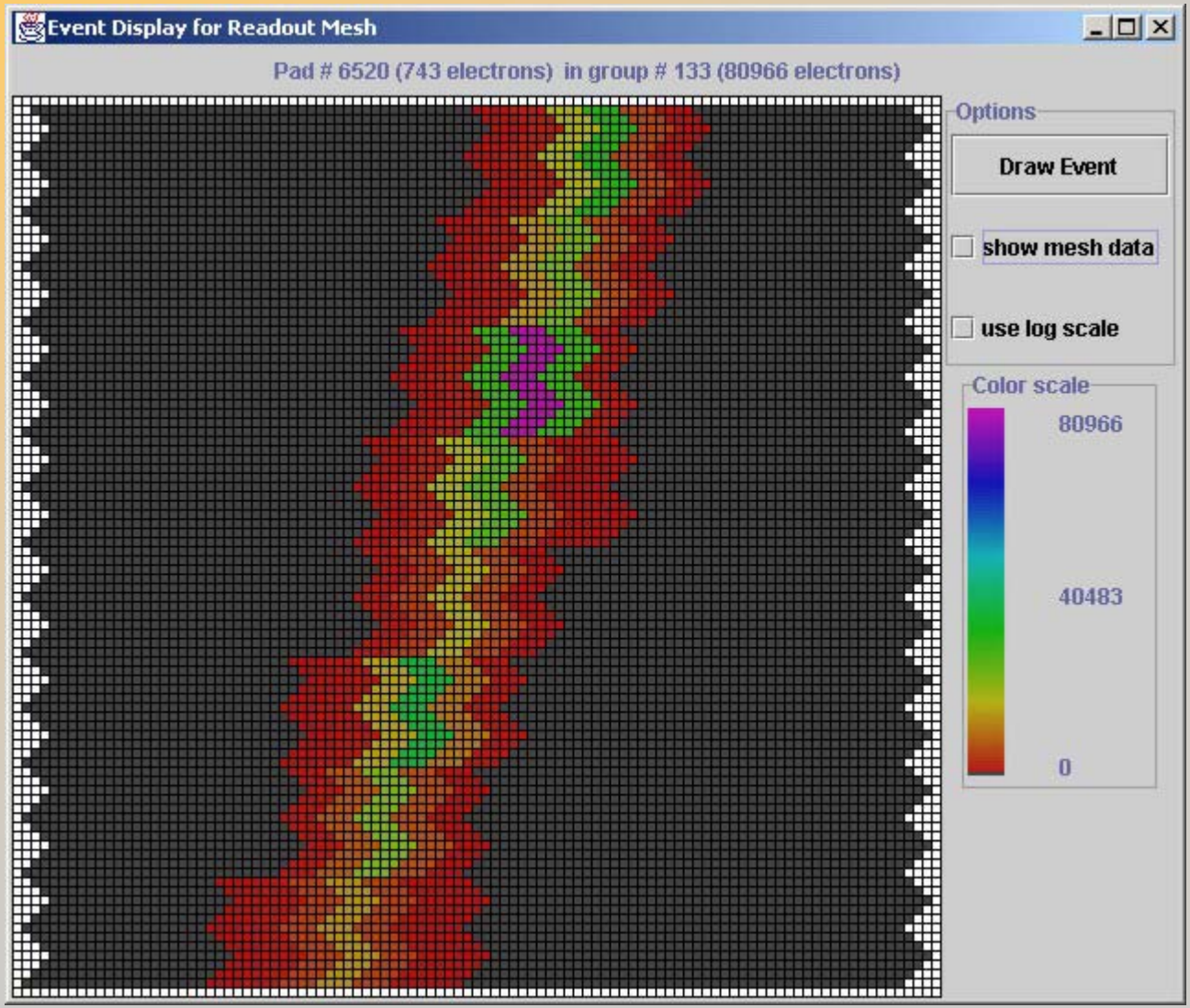
Designing readout pads



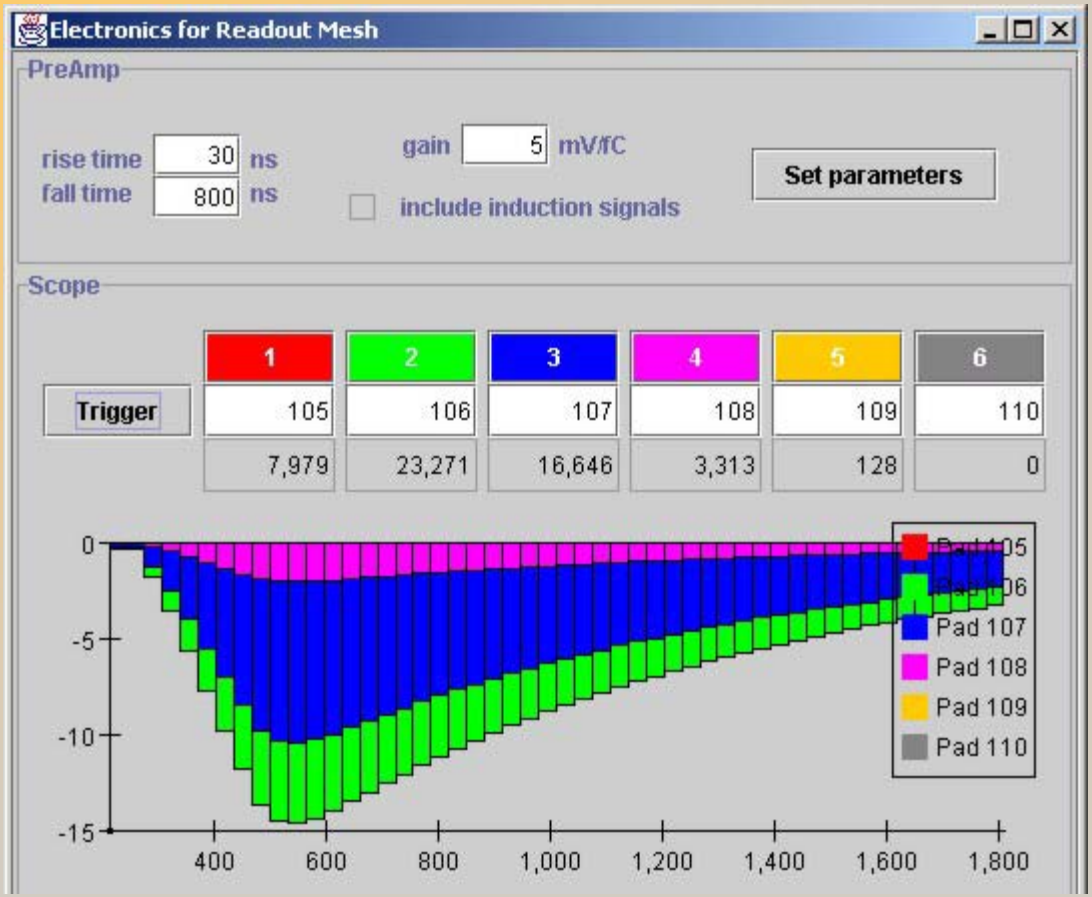
Adding an ionization track



Signals on pads

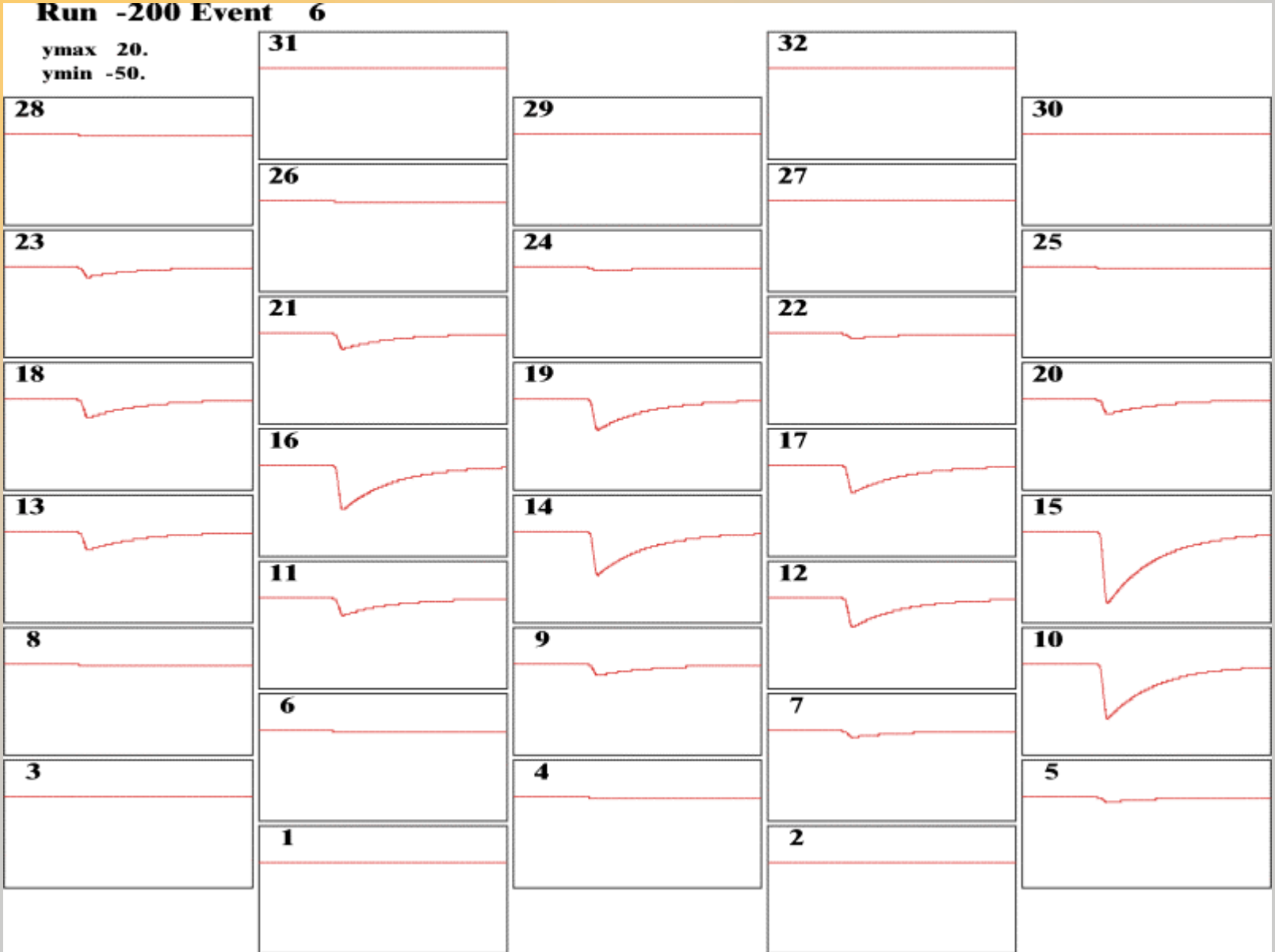


Signals on pads



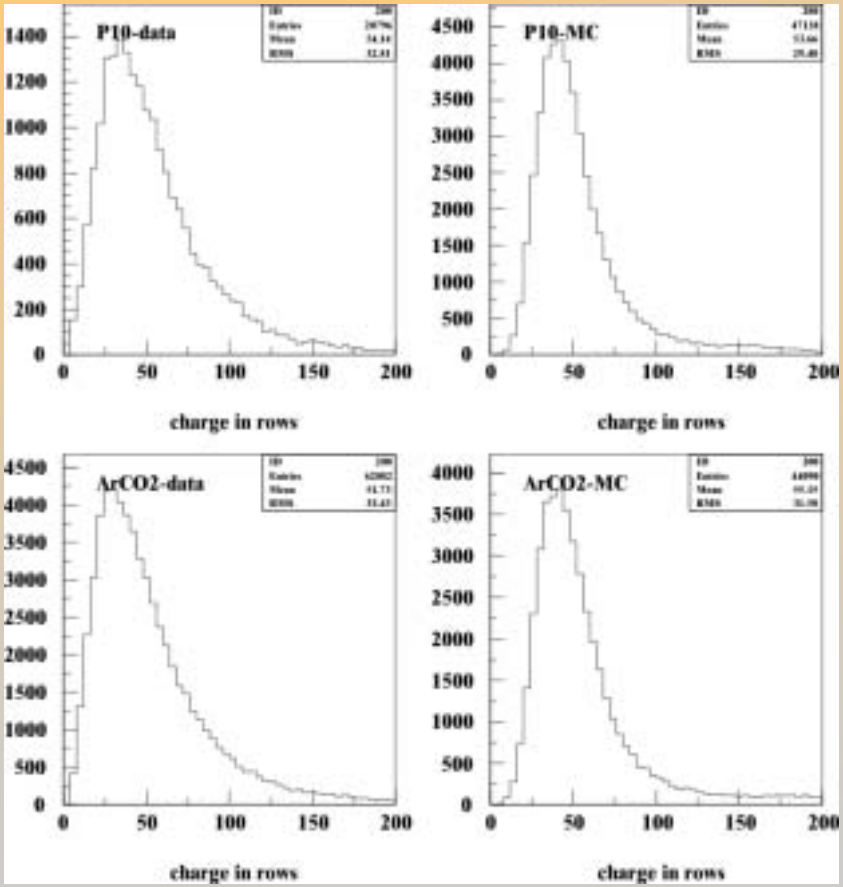
Data can be written to disk for “offline” analysis…

Comparison with prototype TPC data

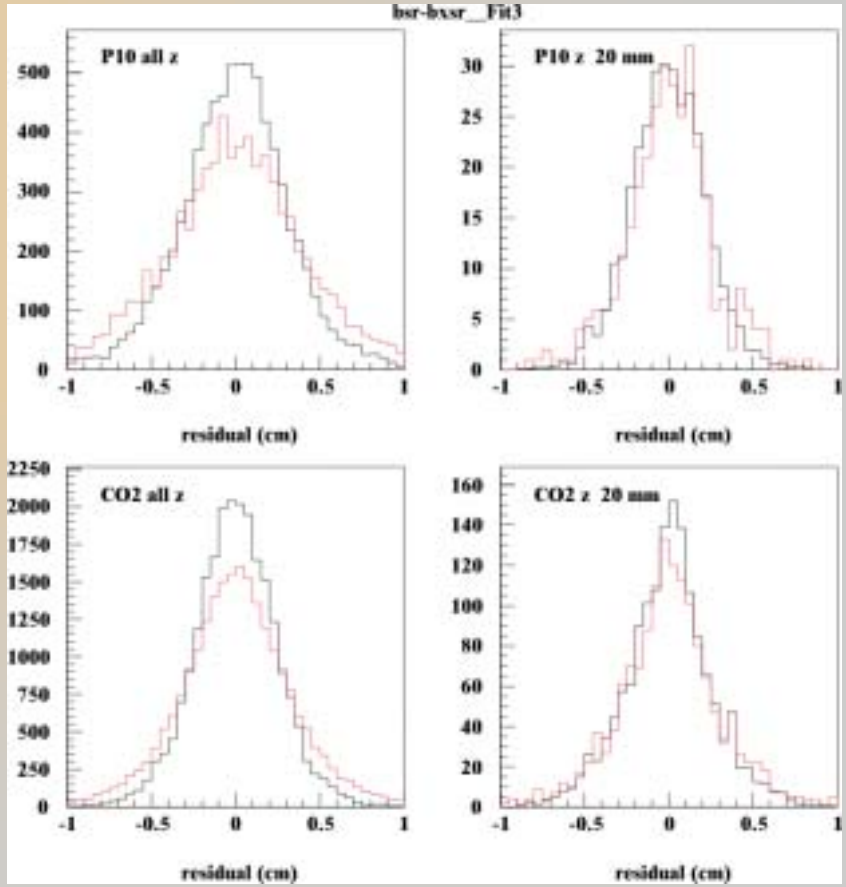


Comparison with prototype TPC data

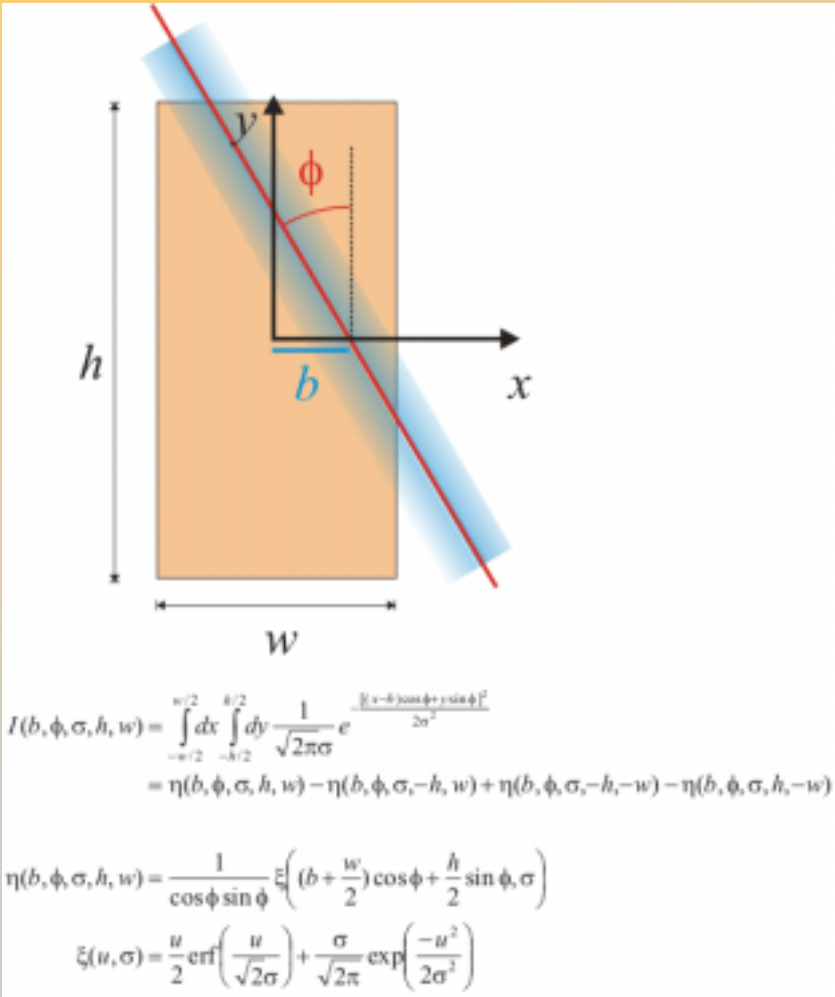
Row charge



Track residuals



Track fitting

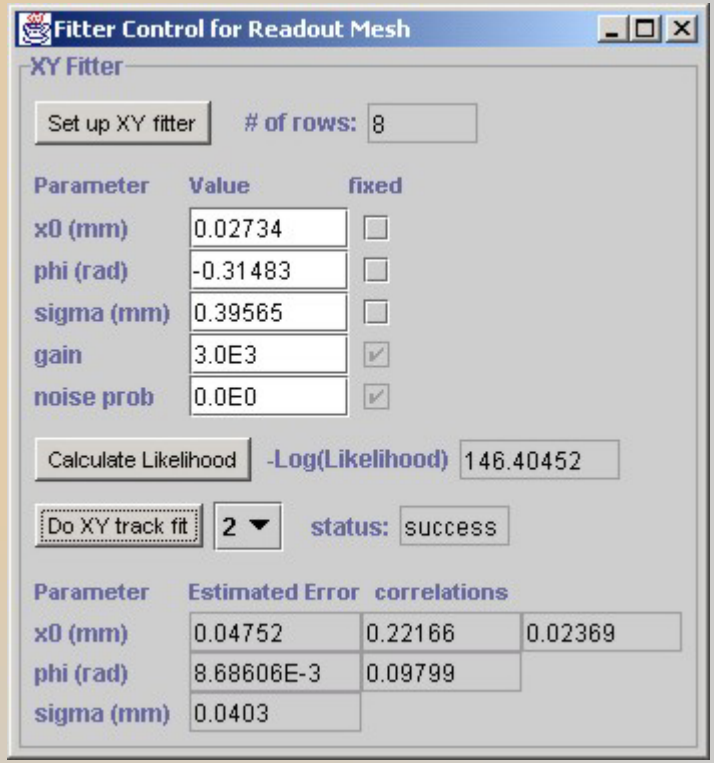


$$I(b,\phi,\sigma,h,w) = \int_{-w/2}^{w/2} dx \int_{-h/2}^{h/2} dy \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{[(x-b)\cos\phi + y\sin\phi]^2}{2\sigma^2}}$$

$$= \eta(b,\phi,\sigma,h,w) - \eta(b,\phi,\sigma,-h,w) + \eta(b,\phi,\sigma,-h,-w) - \eta(b,\phi,\sigma,h,-w)$$

$$\eta(b,\phi,\sigma,h,w) = \frac{1}{\cos\phi \sin\phi} \xi\left((b+\frac{w}{2})\cos\phi + \frac{h}{2}\sin\phi, \sigma\right)$$

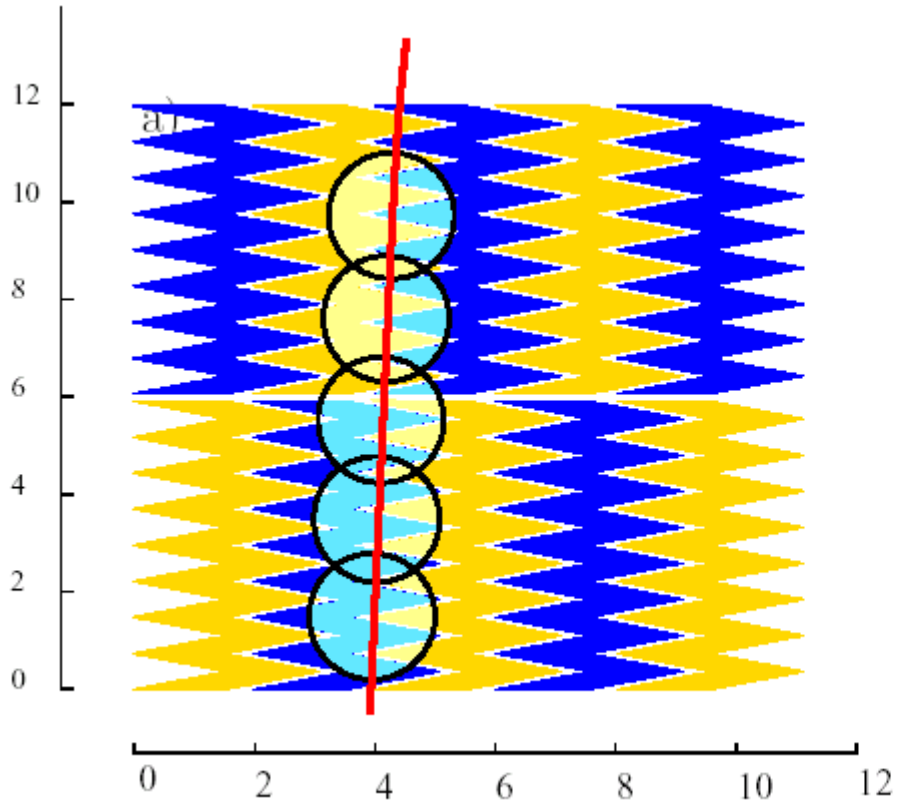
$$\xi(u,\sigma) = \frac{u}{2}\mathrm{erf}\left(\frac{u}{\sqrt{2}\sigma}\right) + \frac{\sigma}{\sqrt{2\pi}}\exp\left(\frac{-u^2}{2\sigma^2}\right)$$

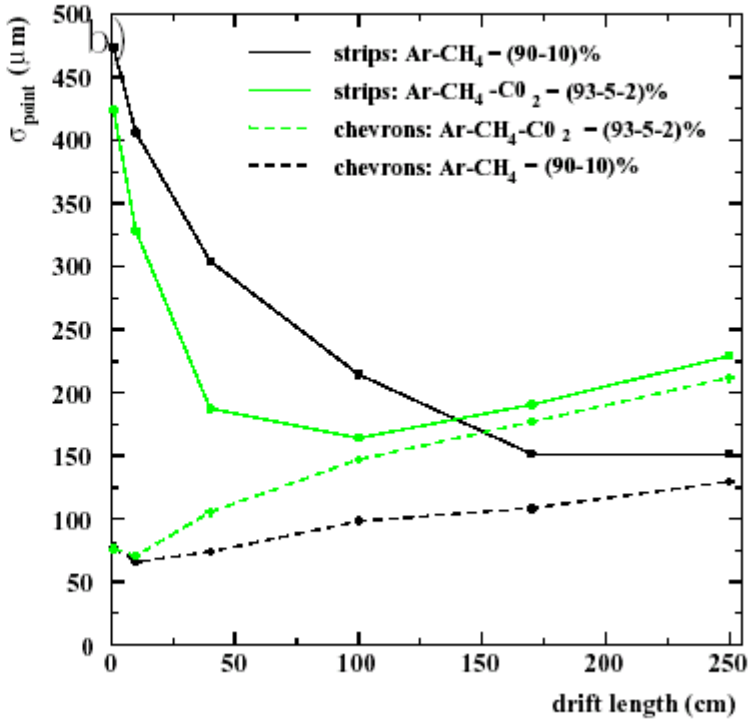


uses the Nonlinear Optimization Java Package (uncmin) translated to java by Steve Verrill

Comparison of pad geometries for GEM

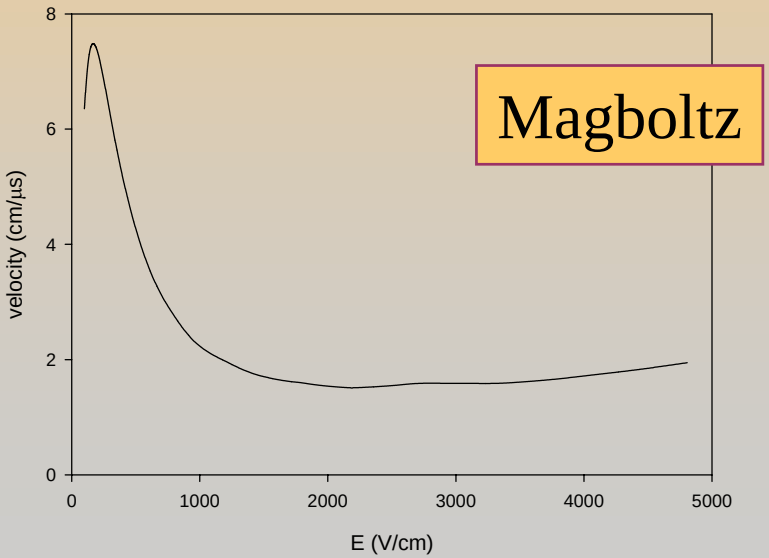
From TESLA TDR: advocates chevrons

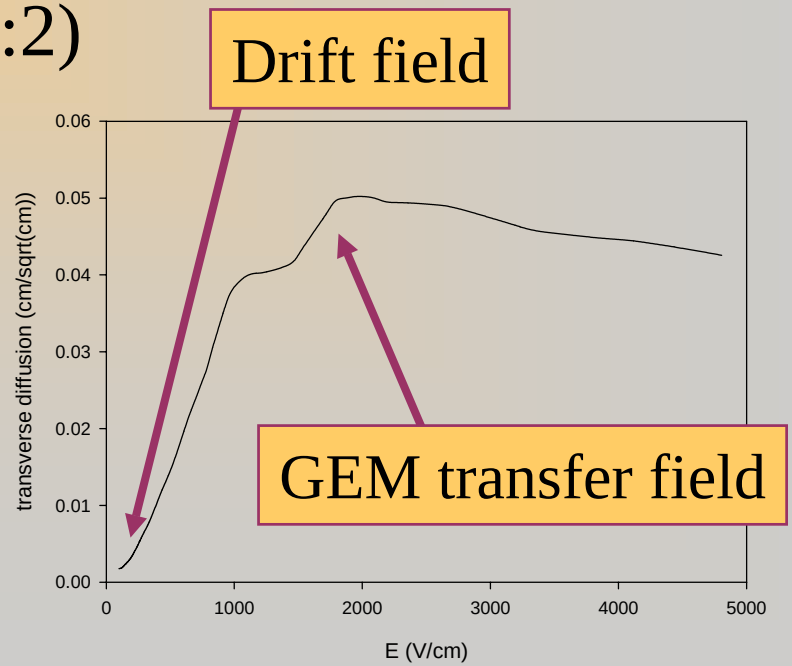




Comparison of pad geometries for GEM

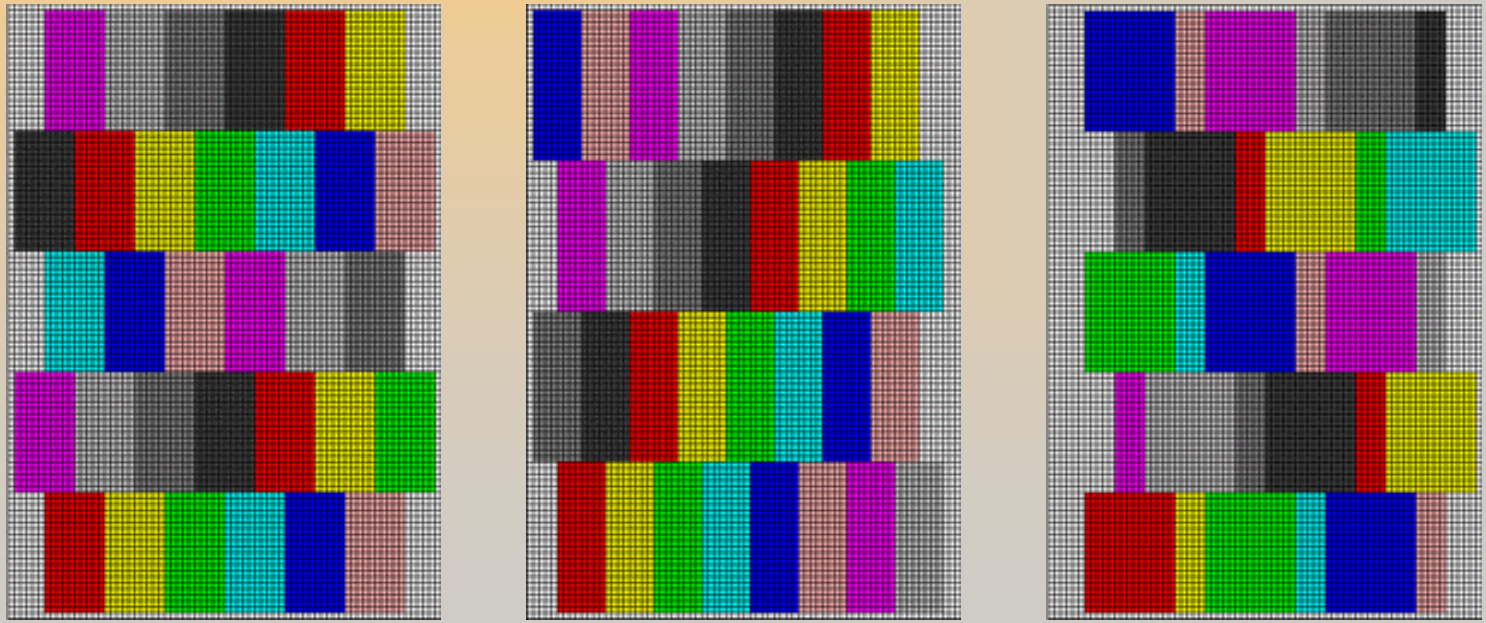
- Current favourite gas mix: Ar CF_4
  - fast at low fields
    - low transverse diffusion in magnetic fields
  - larger diffusion at higher fields
  - Example: Ar CF_4 (98:2)





Comparison of pad geometries for GEM

- Single tracks with $-0.1 < \phi,\psi < 0.1$
- Seven pad geometries sample same ionization



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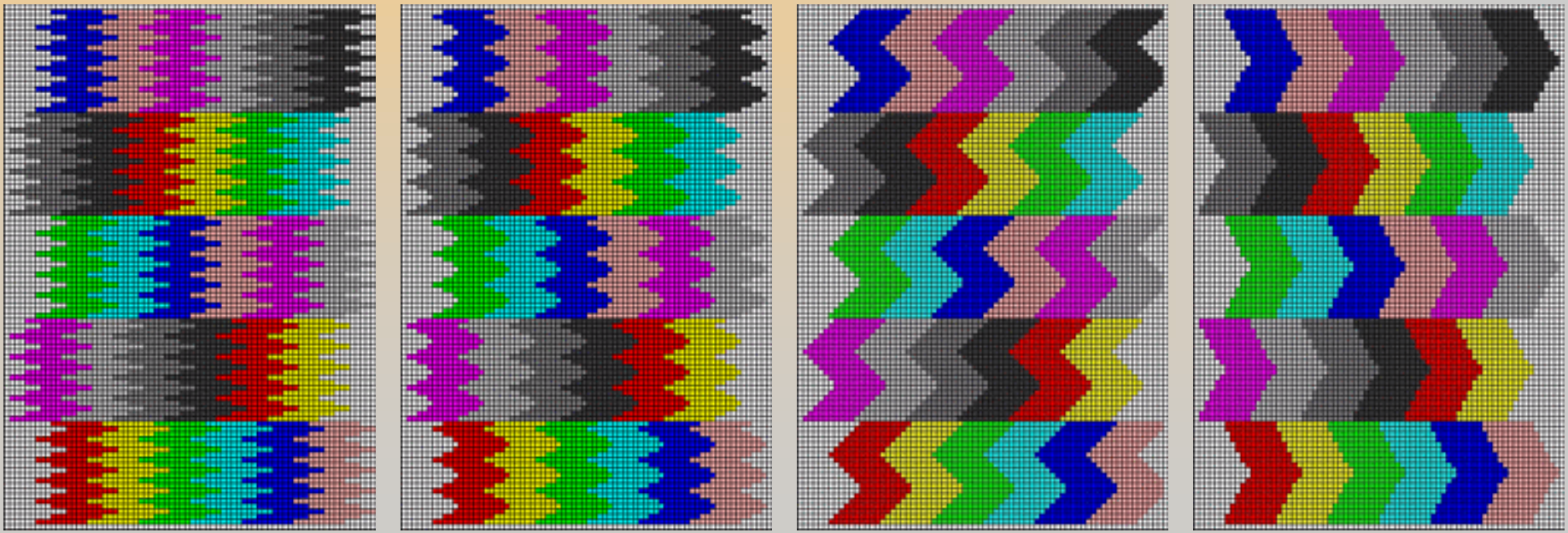

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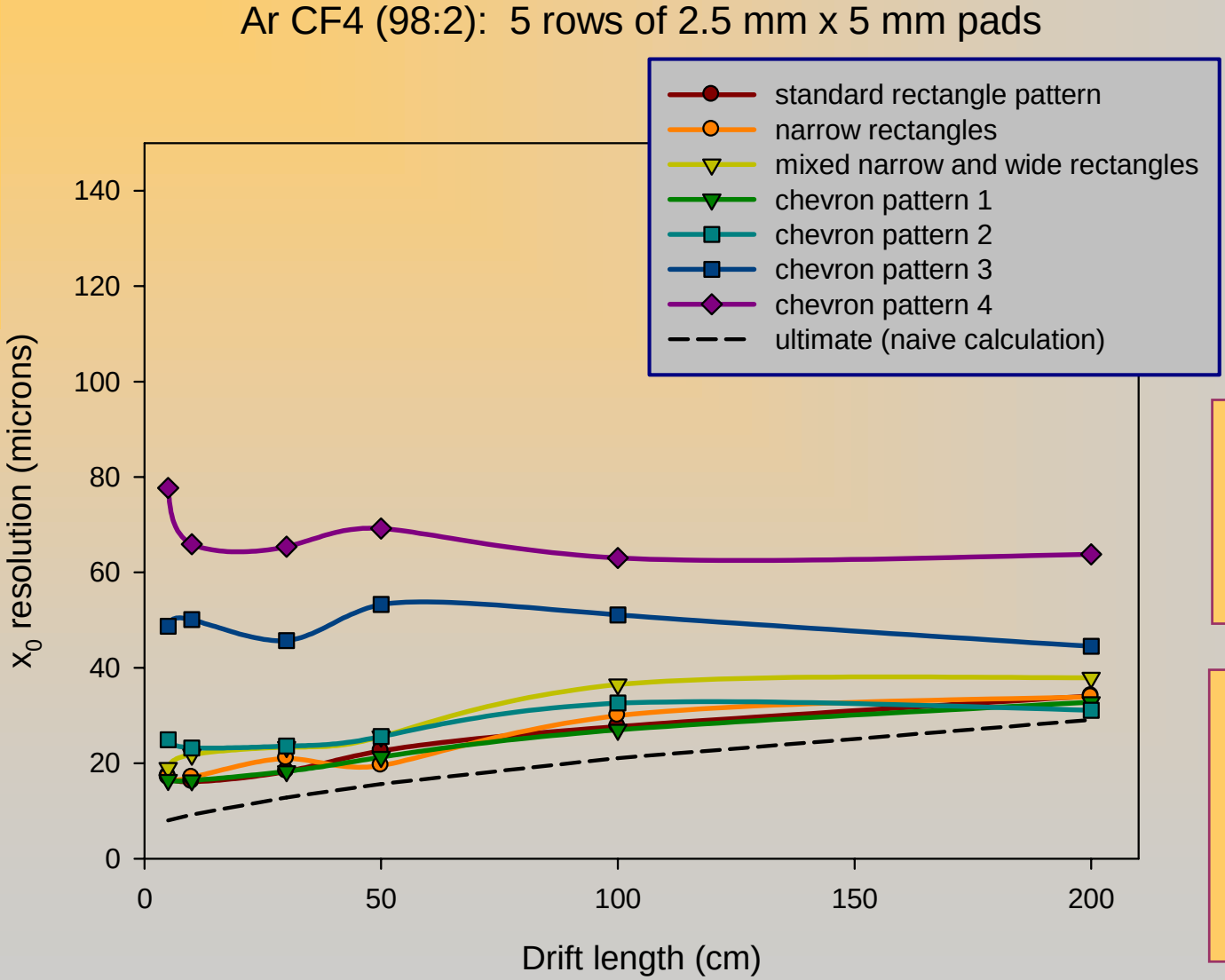
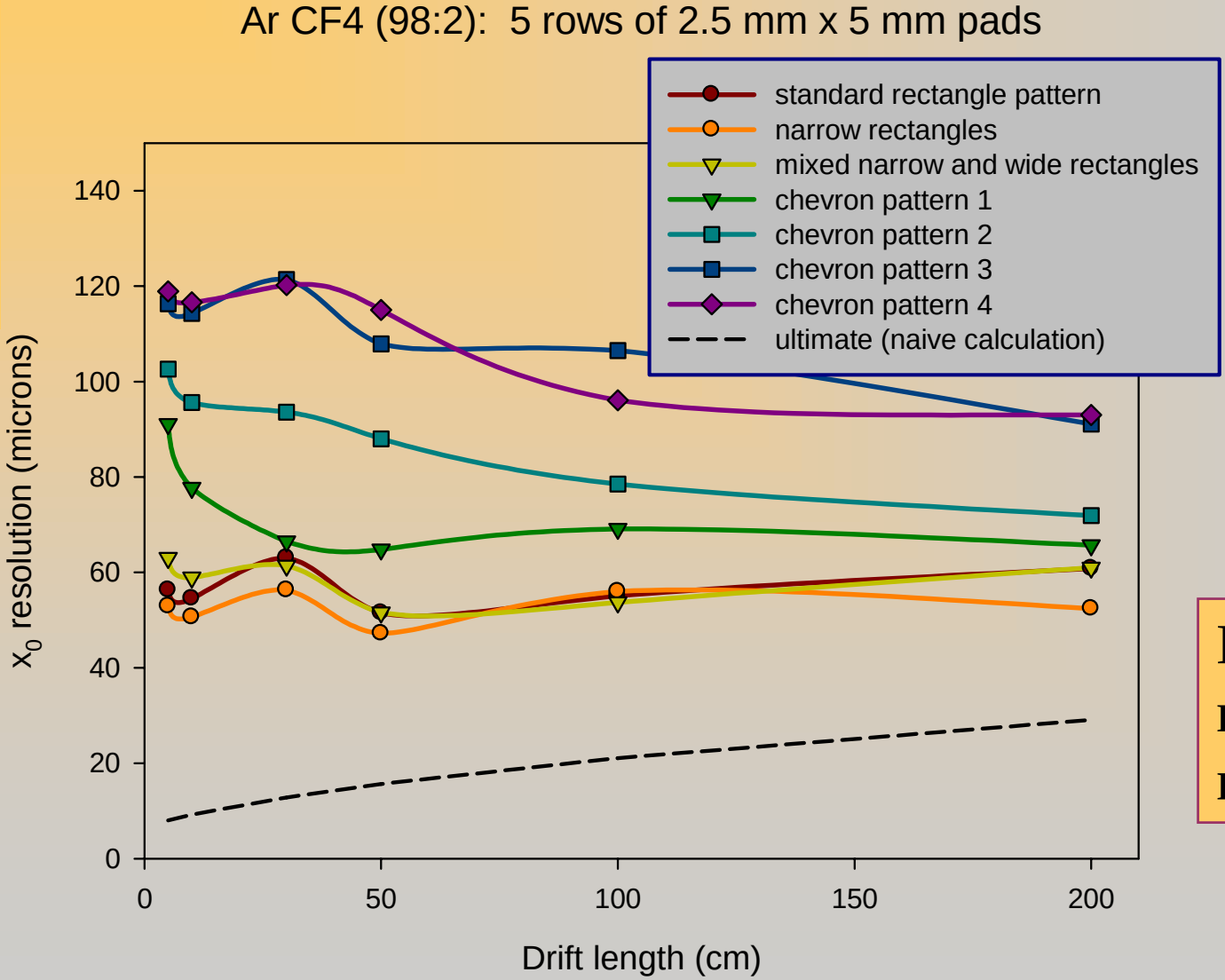


Defocussing in 1 cm GEM gap

Chevrons unnecessary in Ar CF_4 GEM TPC

Comparison of pads for Micromegas



Defocussing required for micromegas

Future possible development

- Include cluster size distributions calculated by HEED
- Add noise: electronic & random SR conversions
- Include “offline analysis”

- Question: If other groups interested in the program, how best to allow for group development?

- To download program, go to:

  http://www.physics.carleton.ca/~karlen/gem/simulation