TPC Readout R&D in Canada

Santa Cruz Linear Collider Retreat, June 27-29, 2002

R. Carnegie, M. Dixit, F. Hartop, H. Mes, E. Neuheimer, A. Rankin, K. Sachs, V. Strickland – Carleton University

J.-P. Martin – University of Montreal

D. Karlen – Carleton / Victoria

TPC Readout R&D in Canada

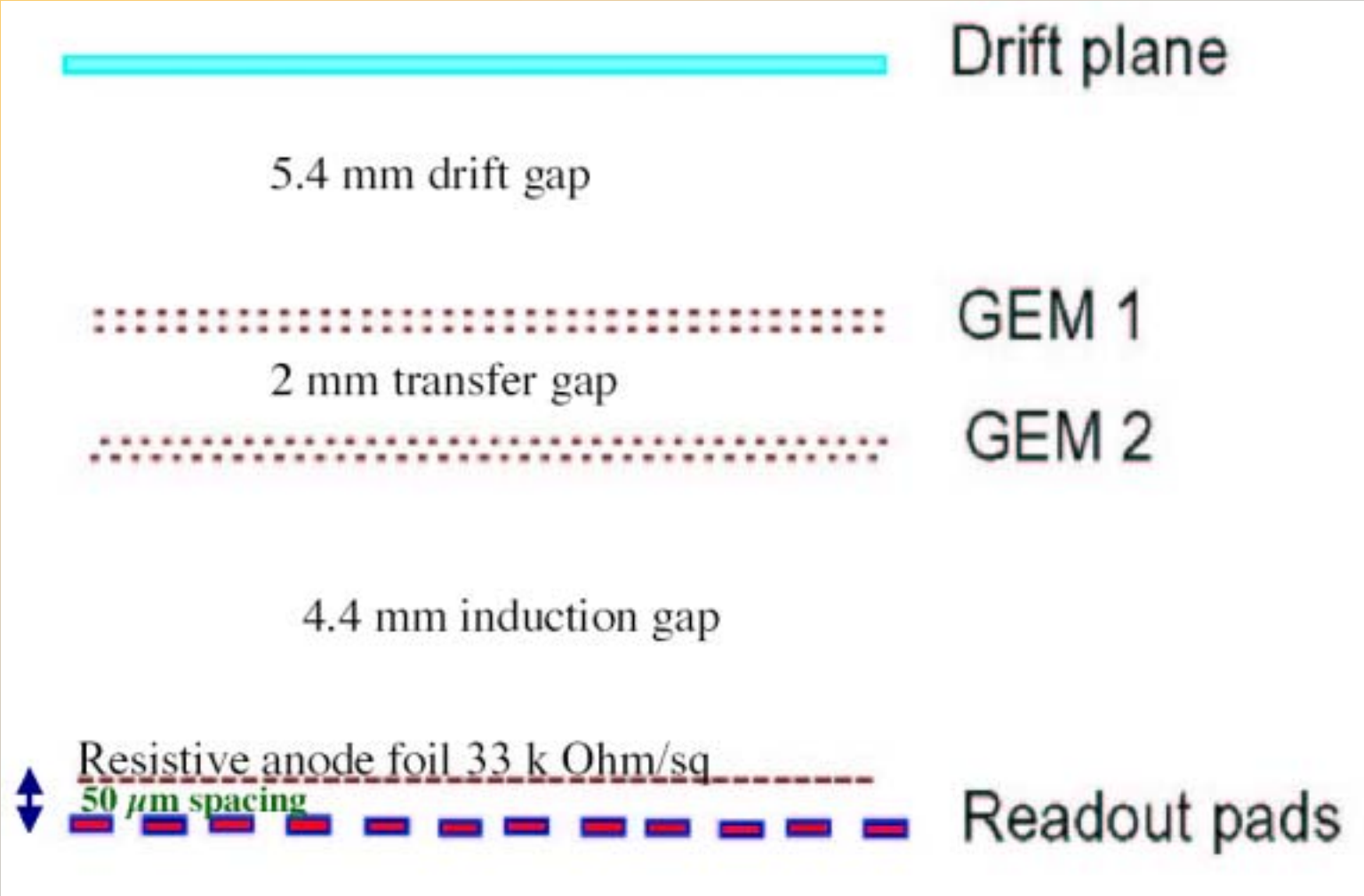
- Past work on GEM based readout:
  - test cell for space point resolution studies with collimated x-ray source
  - 15 cm drift length TPC for tracking resolution studies

- New developments (since Chicago):
  - charge dispersion
  - TPC simulation package
  - new multiplexed TPC readout structure
  - new TPC under construction for magnetic field tests

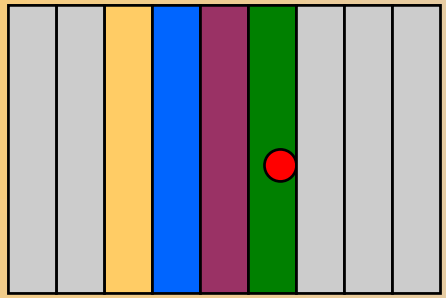
Charge dispersion with resistive anodes

- For some TPC readout designs, the transverse size of charge clouds can be significantly smaller than the pad size
  - would result in degraded resolution
- One possible solution is to spread out the signals over wider area using a resistive anode
  - measurements are underway to determine if this is a viable solution

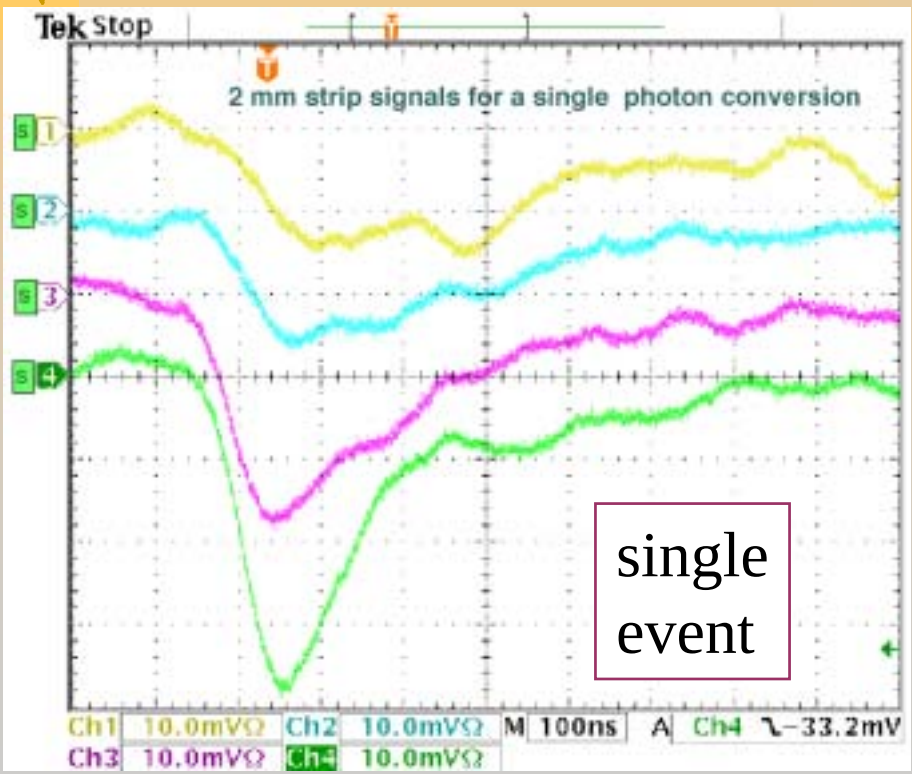
Resistive anode test setup

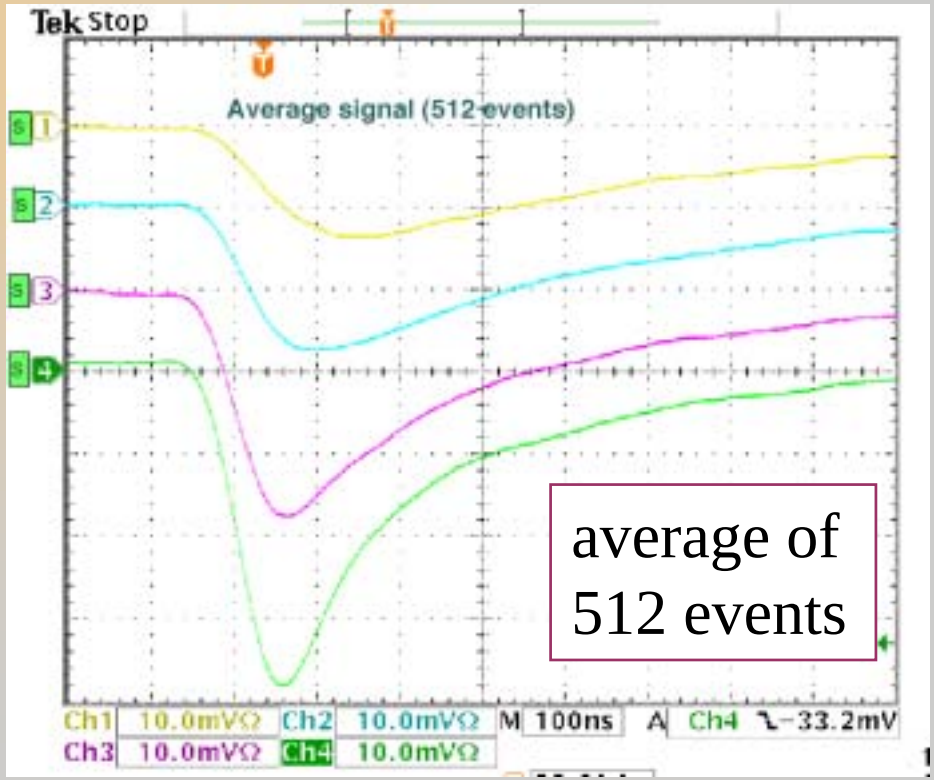


Observed signals



2.5 mm pitch strips





Theory…

2D analog of telegraph equation

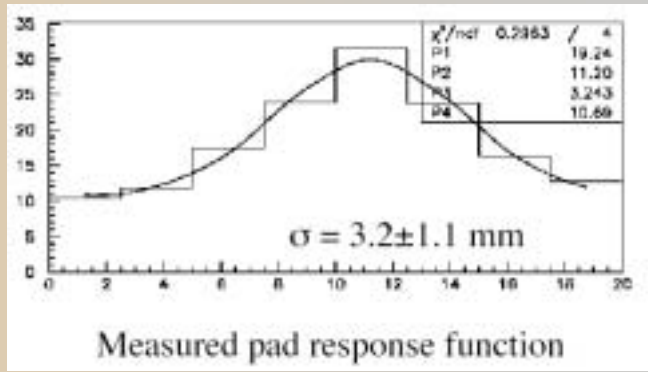
Consider a GEM with a resistive anode. Anode collects avalanche charge. Any localized charge signal will spread radially with time. The 2-D Telegraph equation:

$$\frac{\partial Q}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 Q}{\partial r^2} + \frac{1}{r}\frac{\partial Q}{\partial r}\right] = k^2\left[\frac{\partial^2 Q}{\partial r^2} + \frac{1}{r}\frac{\partial Q}{\partial r}\right]$$

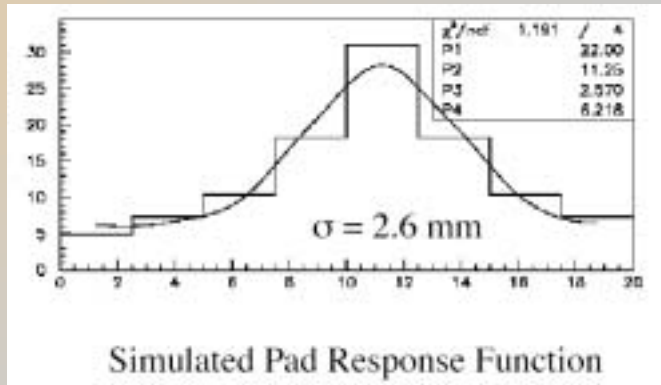
$0 < r < a$ (anode sheet radius)
C = capacitance per unit area
R = surface resistivity (Ohms/□)
L ~ 0
$k^2 = 1/RC$

- Boundary conditions: $Q = f(r)$ at $t = 0$
  $Q = 0$ for $r = a$; $0 \le t \le \infty$
- Solution for initial point charge: Take limit $a \Rightarrow \infty$ for $Q = \delta(r)$ at $t = 0$ with $\int \delta(r)dr = 1$ is given by:

$$Q(r,t) = \frac{1}{2k^2 t} e^{-[r^2/(4k^2 t)]}$$



Measured pad response function

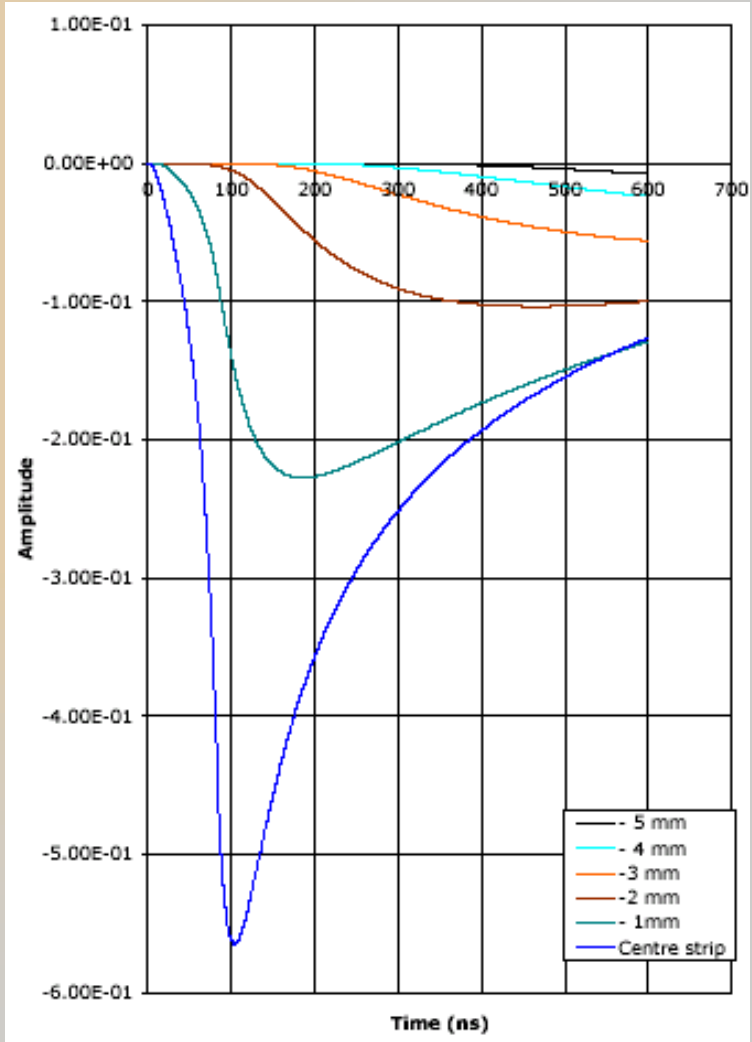


Simulated Pad Response Function

Incorporate finite size of initial charge cluster & amplifier rise & fall time effects to comare to measurement.

Optimization of pad response function

- For 2 MΩ / and 100 μm gap, the PRF is calculated to have a standard deviation of 700 μm
  - measurements are underway to verify this

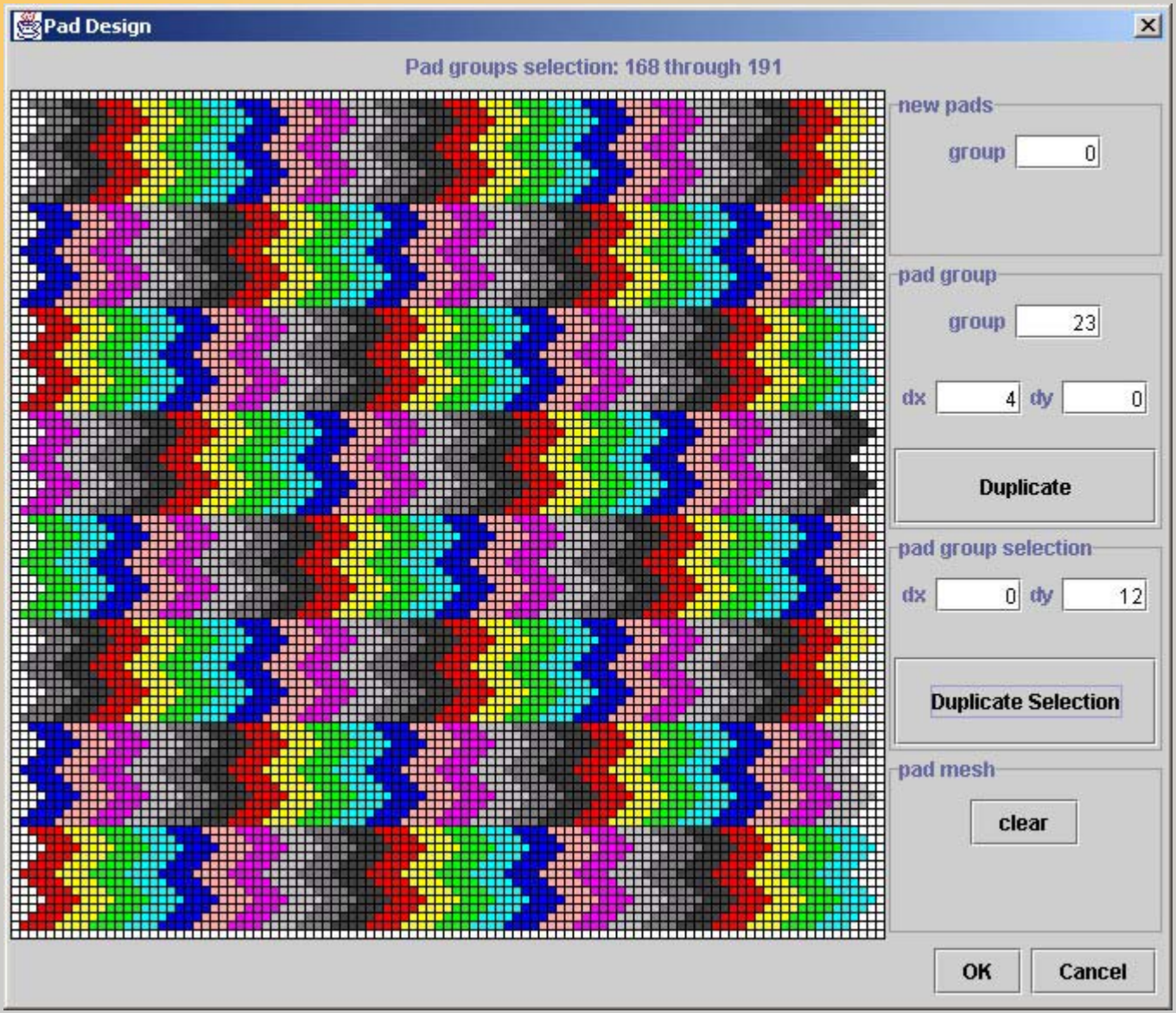


TPC simulation package

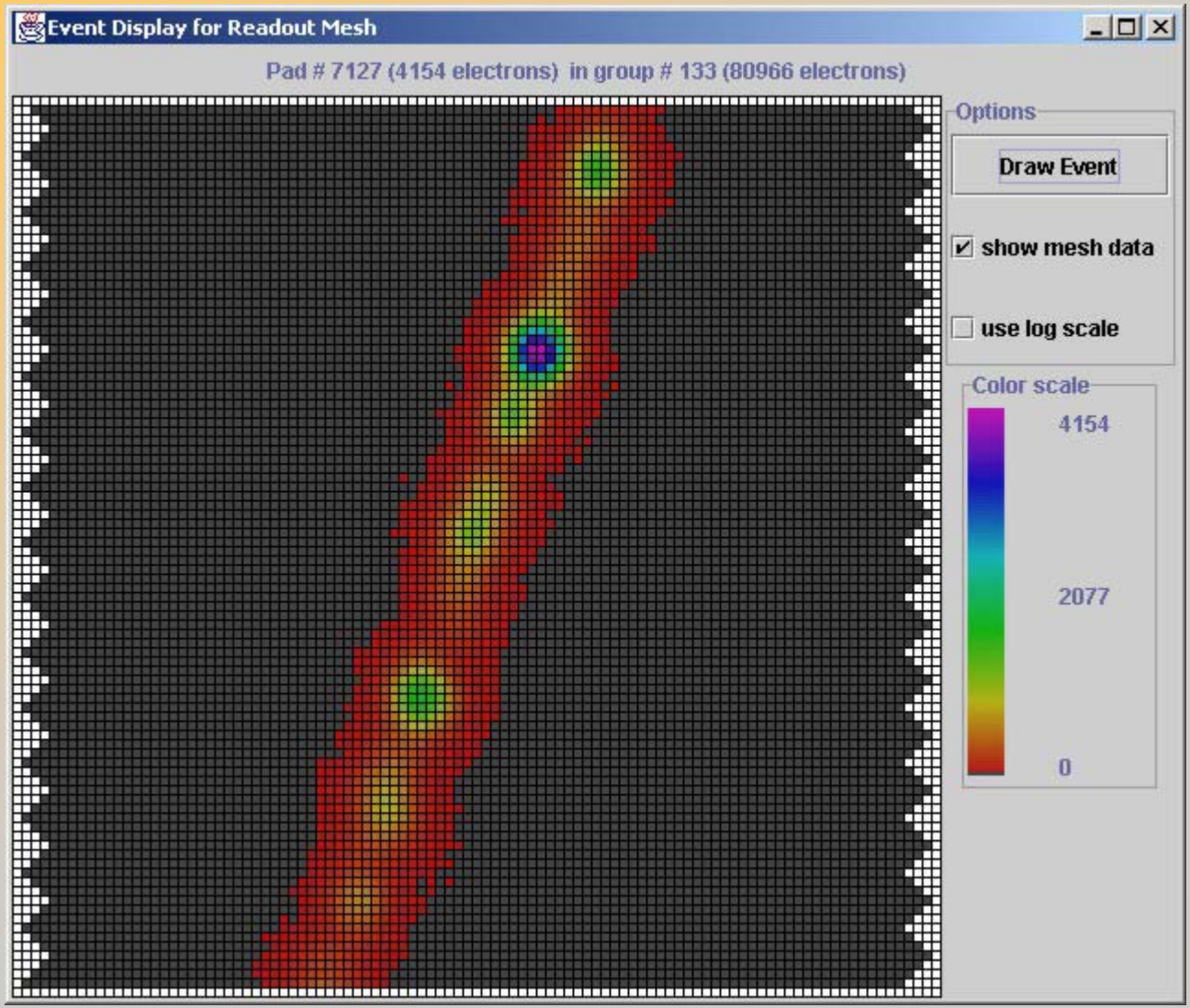
- written in Java
- easy to use
- can build arbitrary TPC with GEM readout
- any readout pad structure can be defined
- sophisticated tracking algorithm

- only simulates direct charge signals
  - does not simulate induced signals

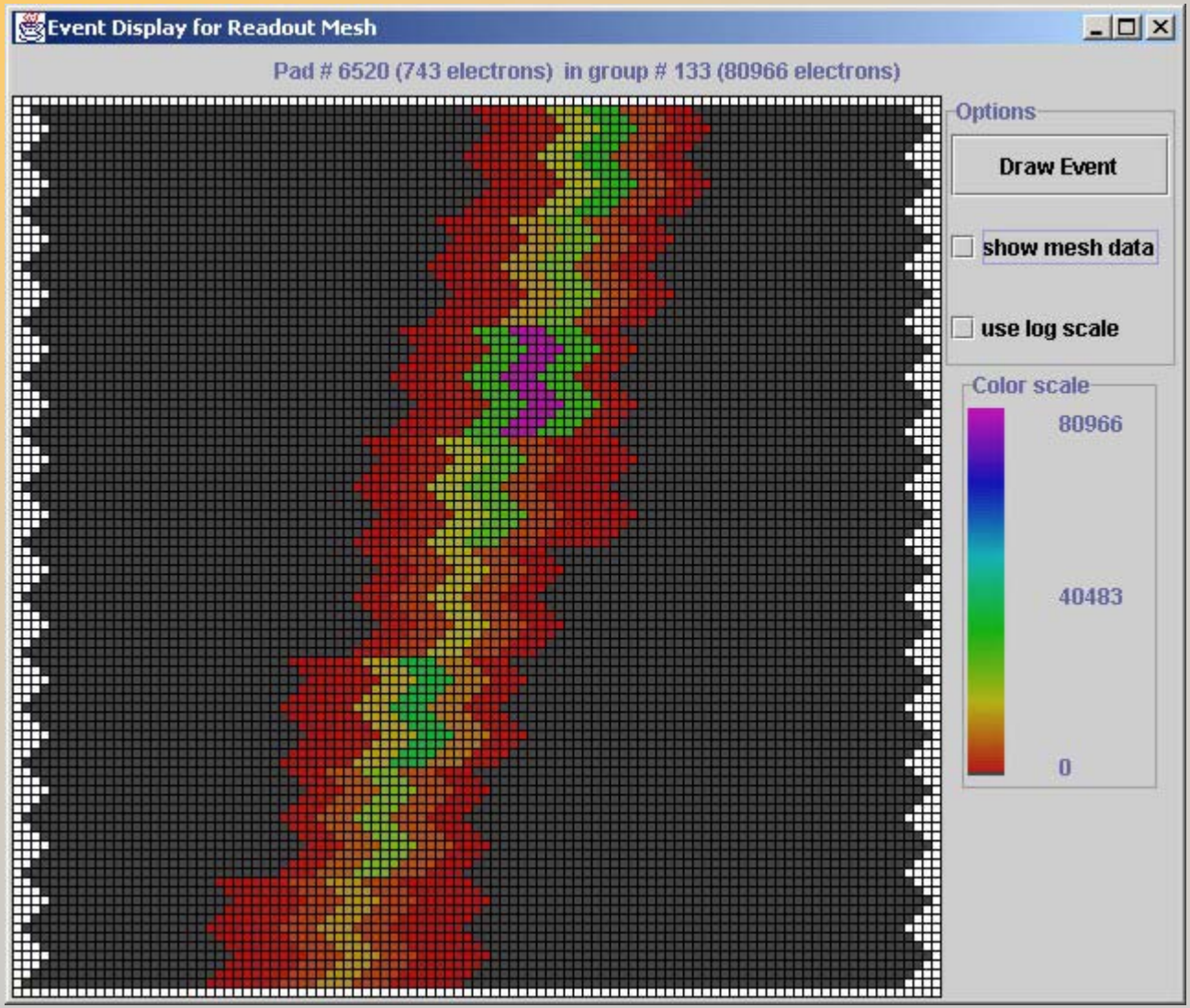
Designing readout pads



Adding an ionization track

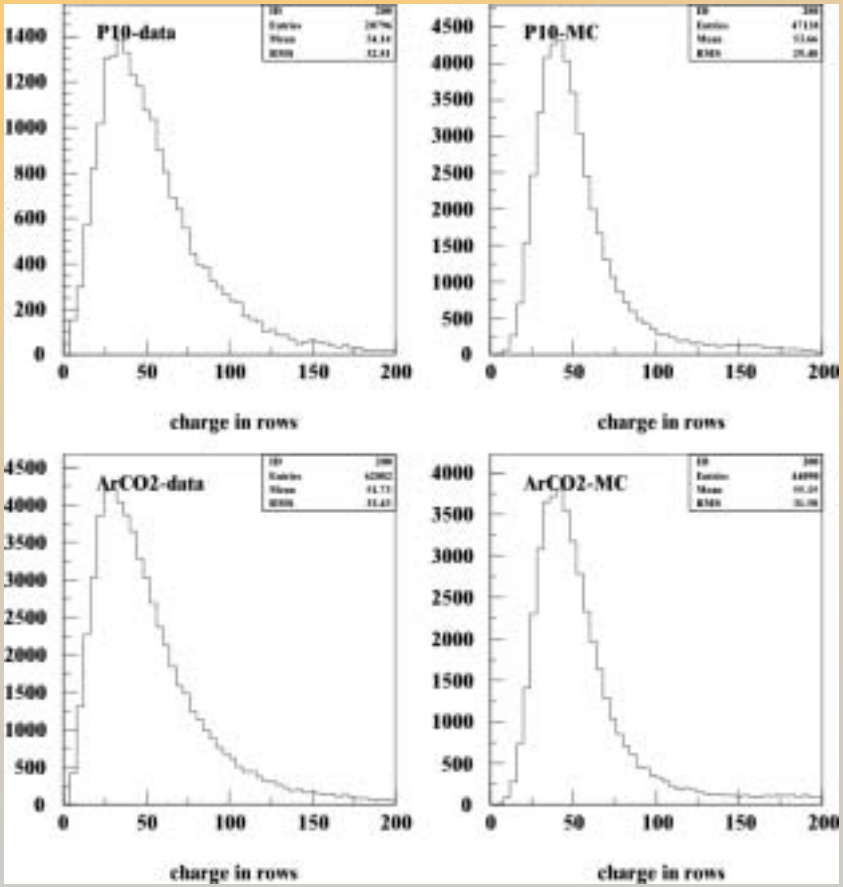


Signals on pads

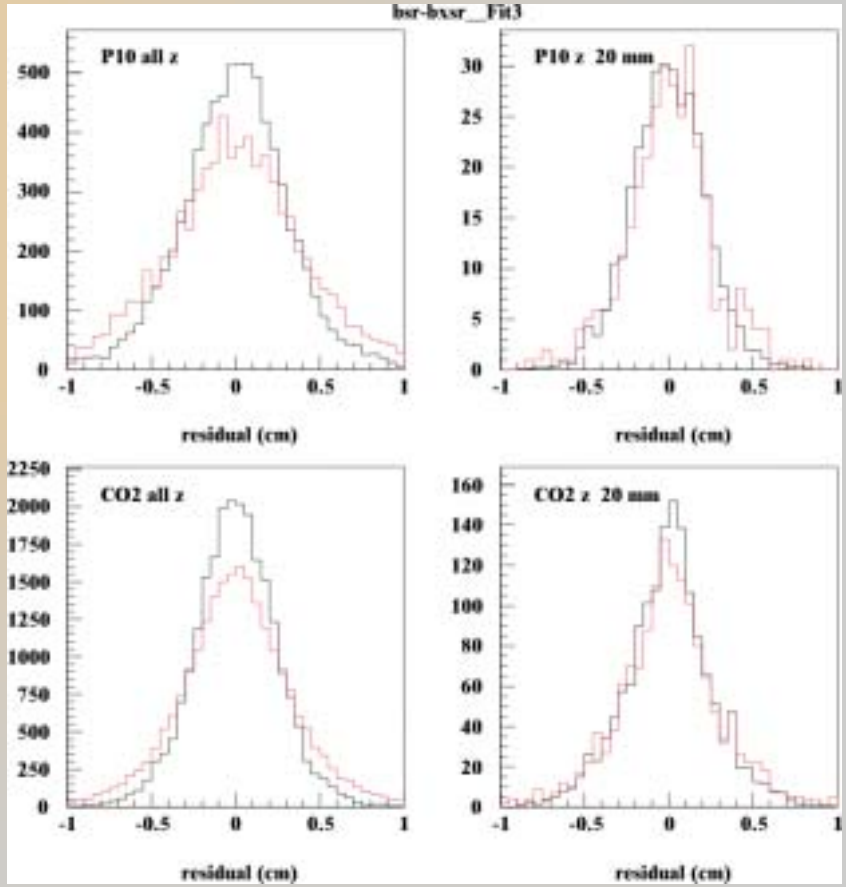


Comparison with prototype TPC data

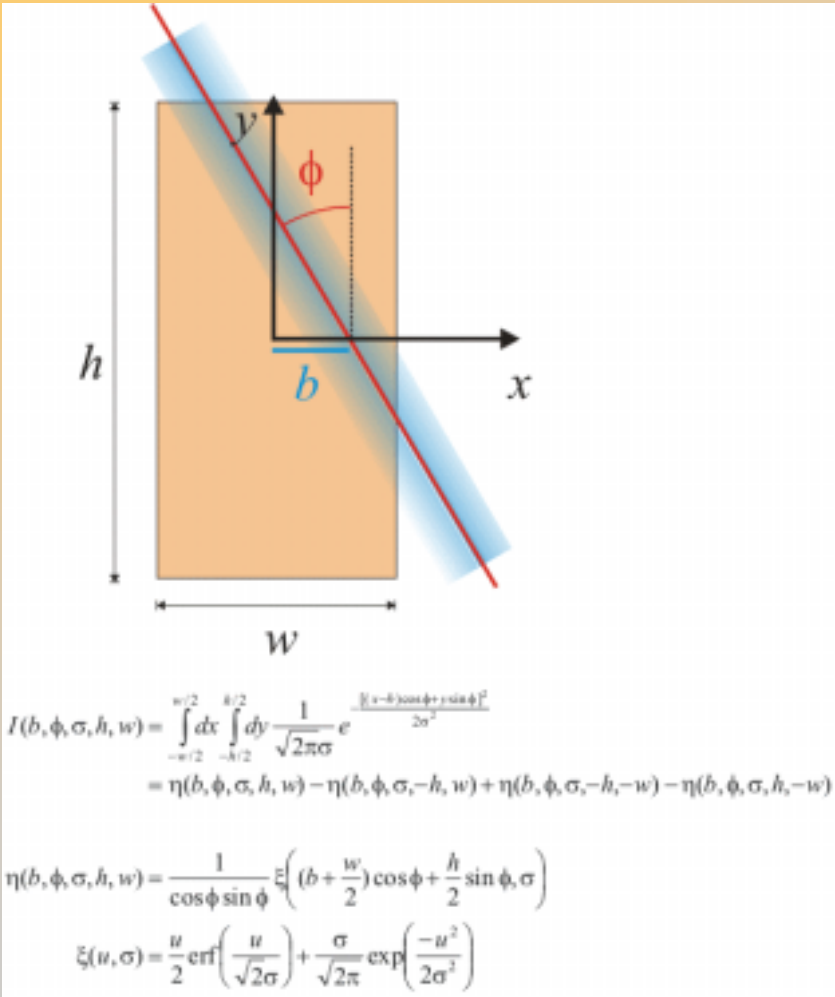
Row charge



Track residuals



Track fitting

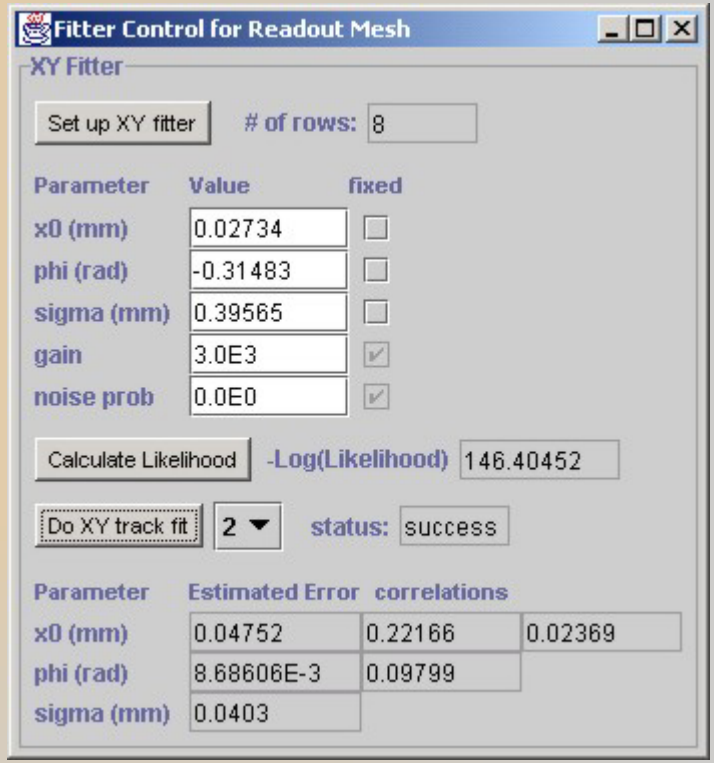


$$I(b,\phi,\sigma,h,w) = \int_{-w/2}^{w/2} dx \int_{-h/2}^{h/2} dy \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{[(x-b)\cos\phi + y\sin\phi]^2}{2\sigma^2}}$$

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

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

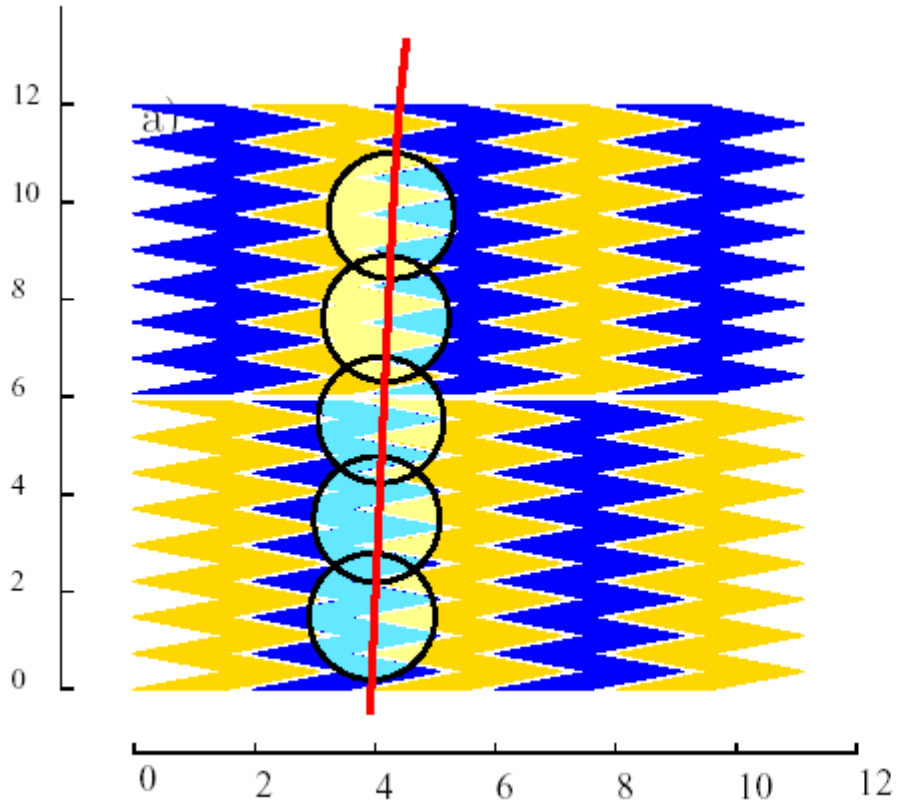
$$\xi(u,\sigma) = \frac{u}{2}\mathrm{erf}\left(\frac{u}{\sqrt{2}\sigma}\right) + \frac{\sigma}{\sqrt{2\pi}}\exp\left(\frac{-u^2}{2\sigma^2}\right)$$

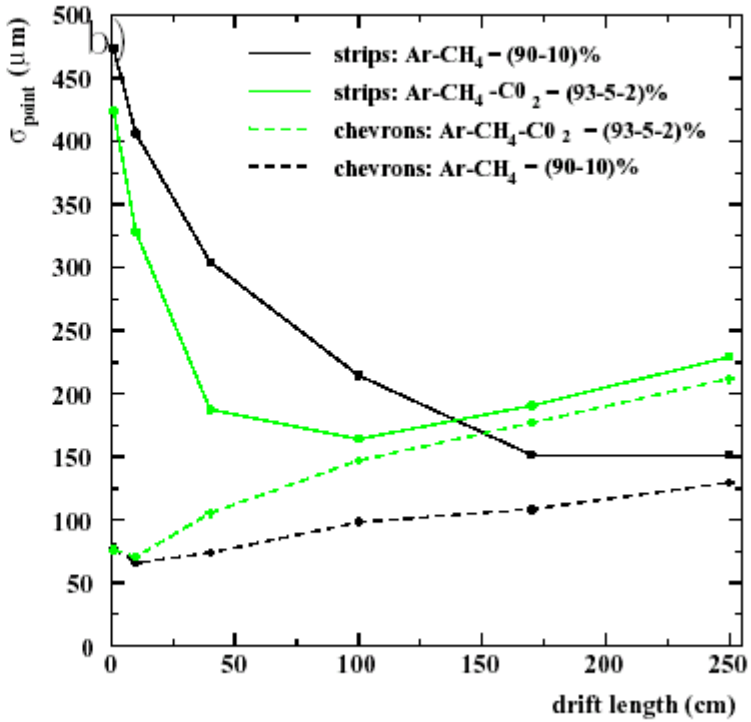


uses the Nonlinear Optimization Java Package (uncmin) translated to java by Steve Verrill

Comparison of pad geometries for GEM

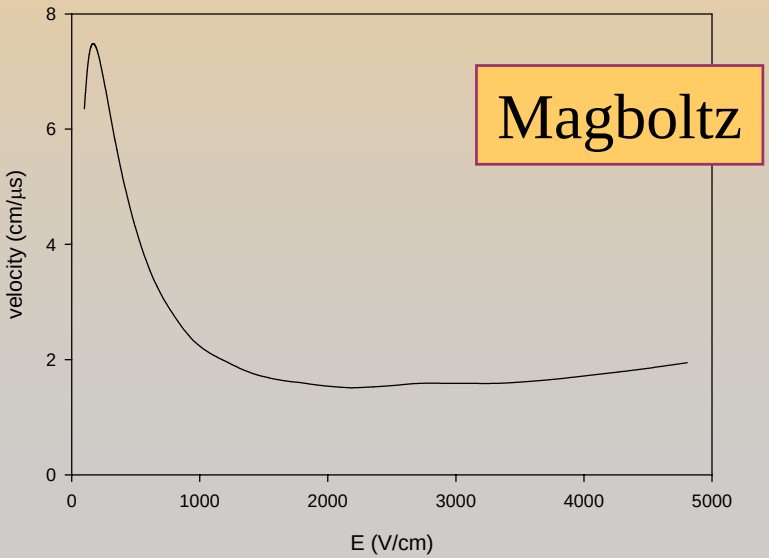
From TESLA TDR: advocates chevrons

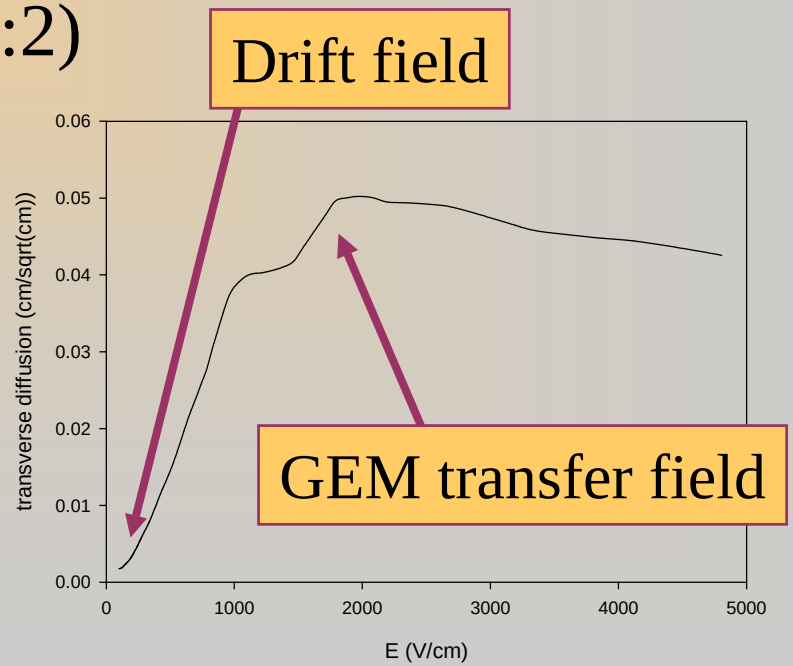




Comparison of pad geometries for GEM

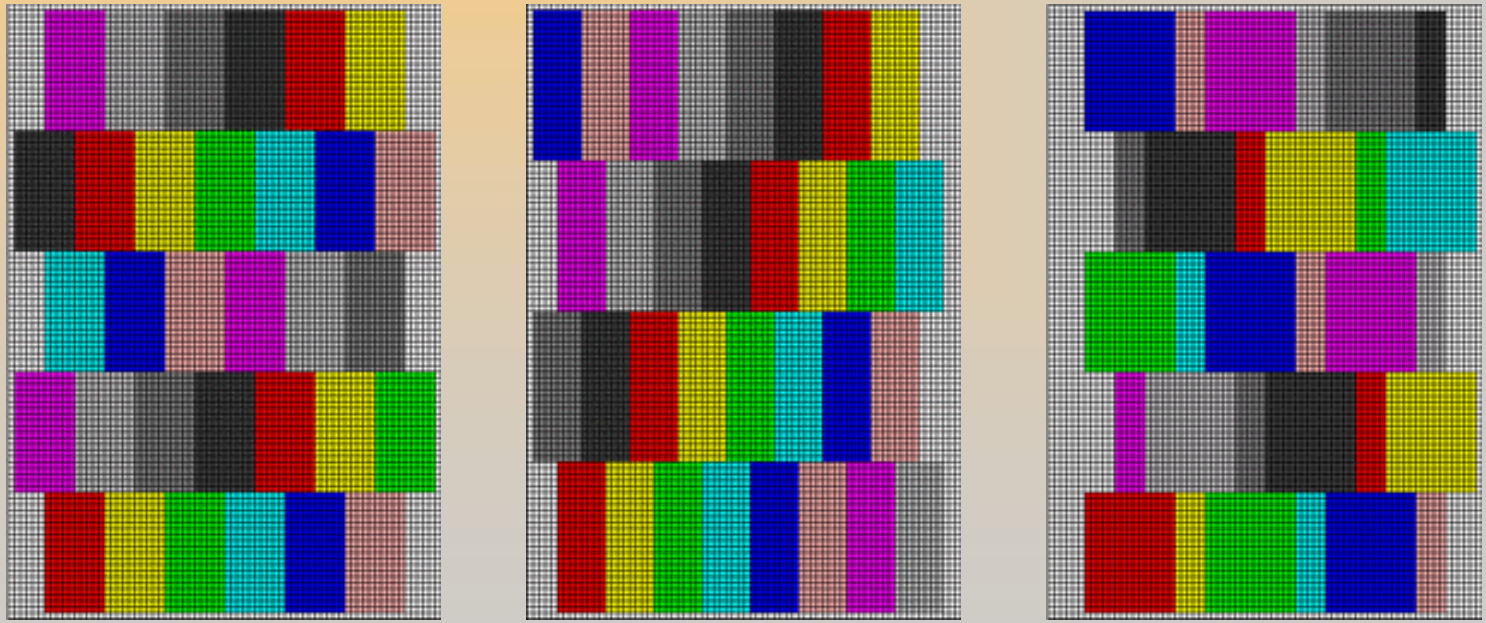
- Current favourite gas mix: Ar CF_4
  - fast at low fields
    - low transverse diffusion in magnetic fields
  - larger diffusion at higher fields
  - Example: Ar CF_4 (98:2)





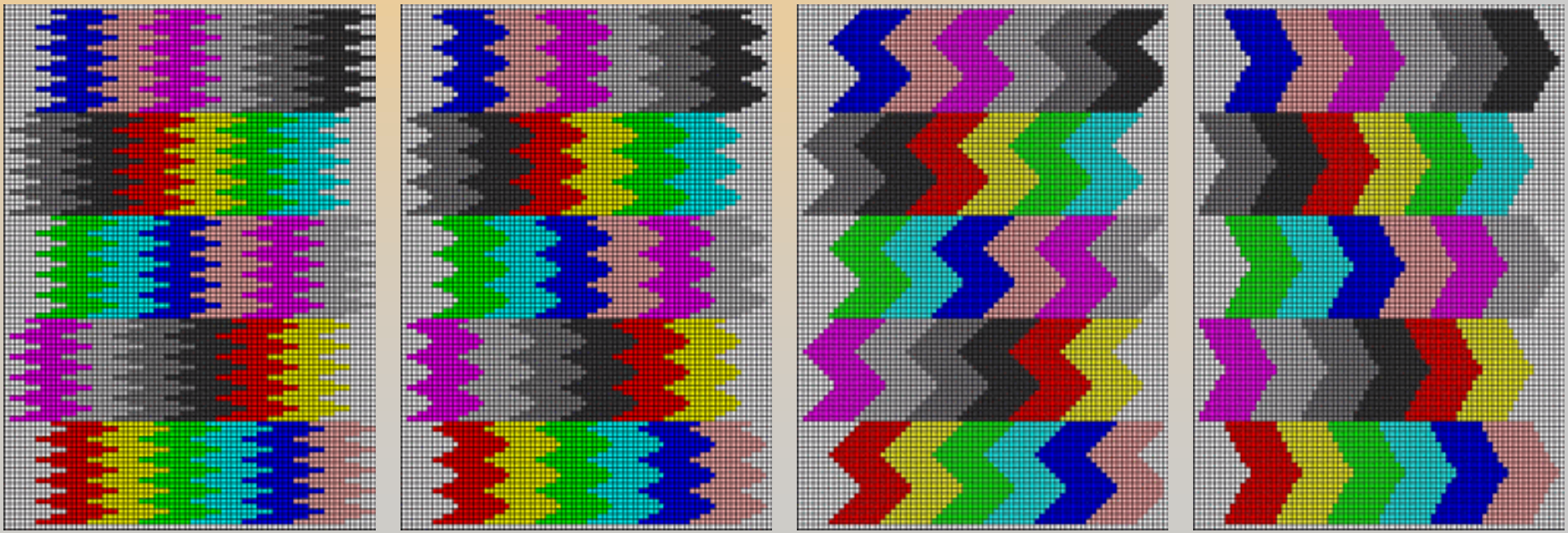
Comparison of pad geometries for GEM

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

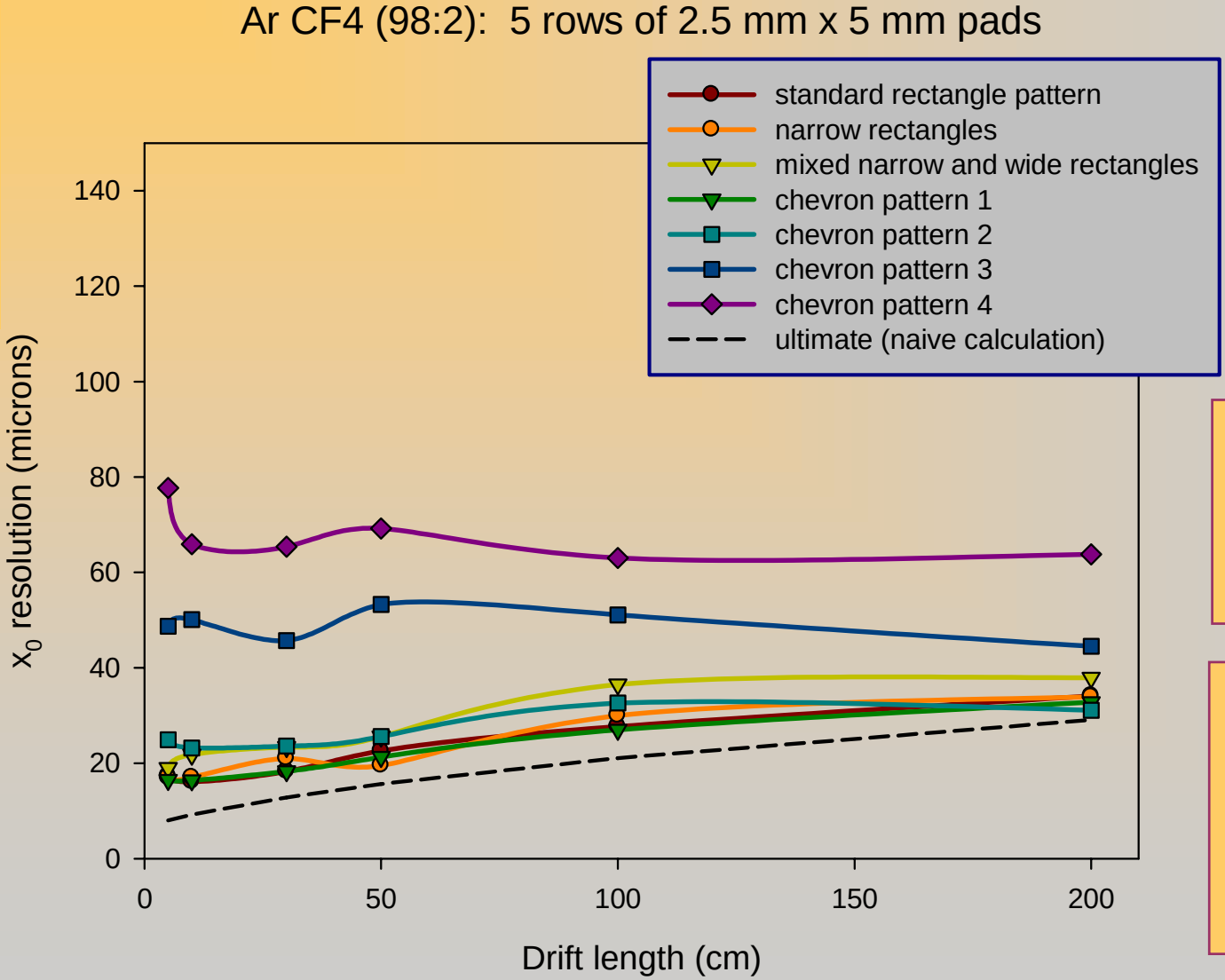


Comparison of pad geometries for GEM

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



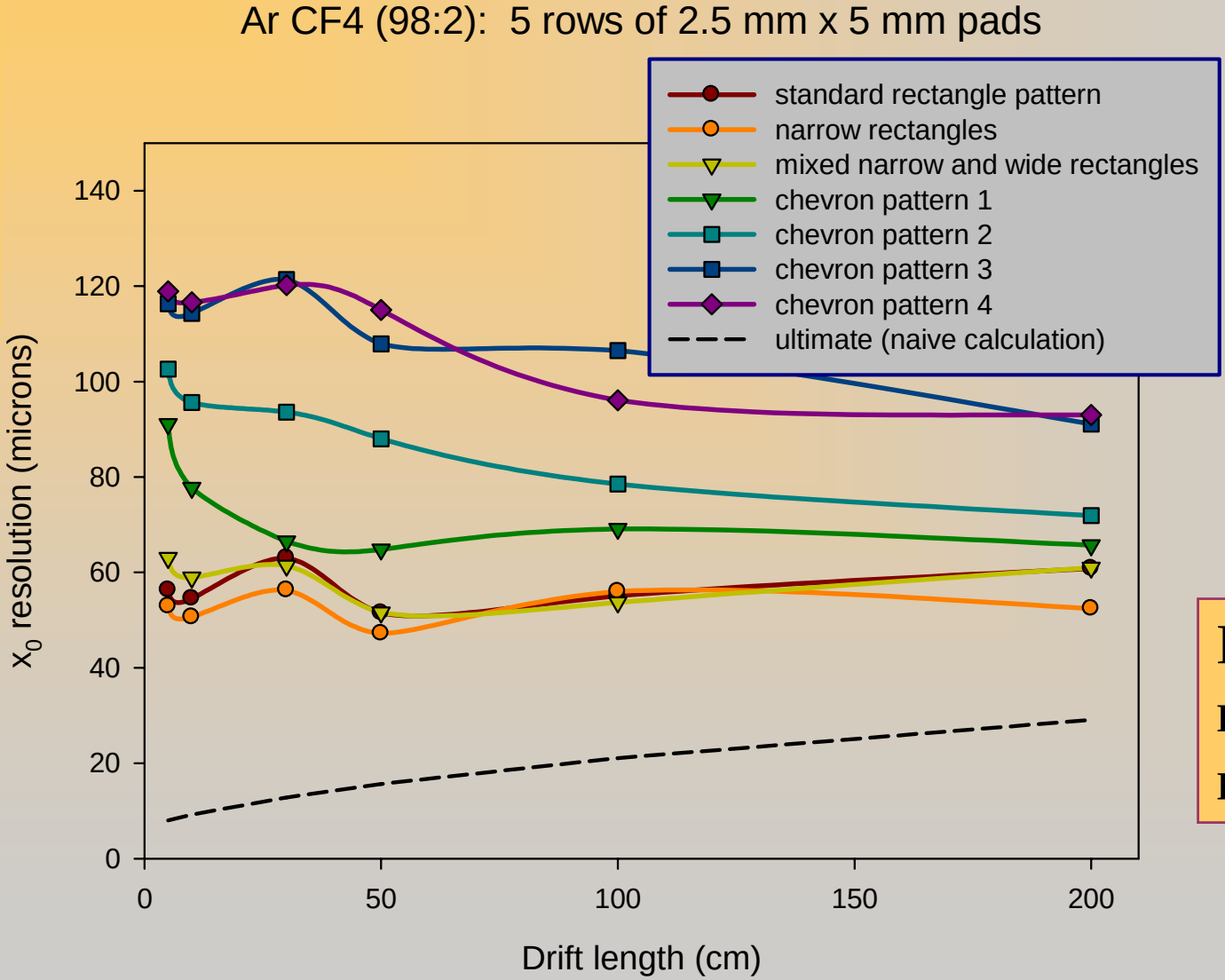
Comparison of pad geometries for GEM



Defocussing in 1 cm GEM gap

Chevrons unnecessary in Ar CF_4 GEM TPC

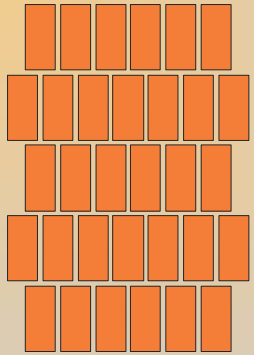
Comparison of pads for Micromegas



Defocussing required for micromegas

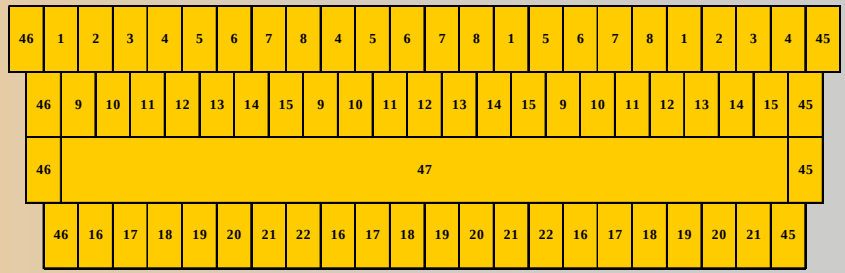
New multiplexed readout structure

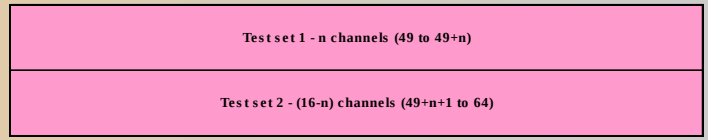
- 3x multiplexing to readout 192 pads with 64 FADC channels
  - easy for cosmics, multiplicity is low!
  - should we consider multiplexing for the real TPC?
  - use long pads for triggering

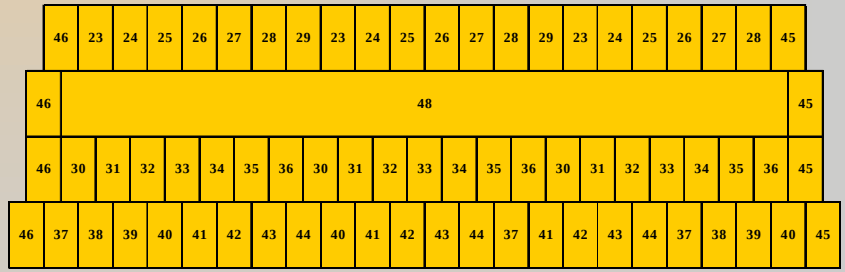


old

installed, taking data



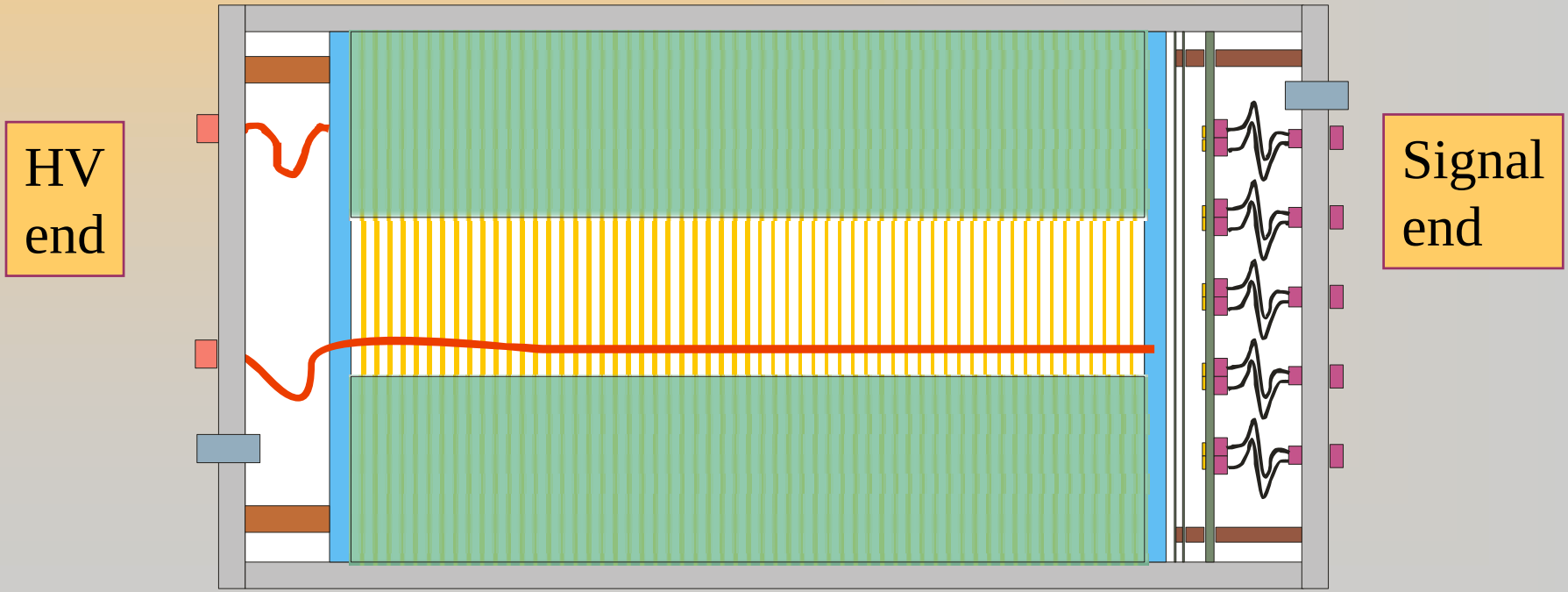




new

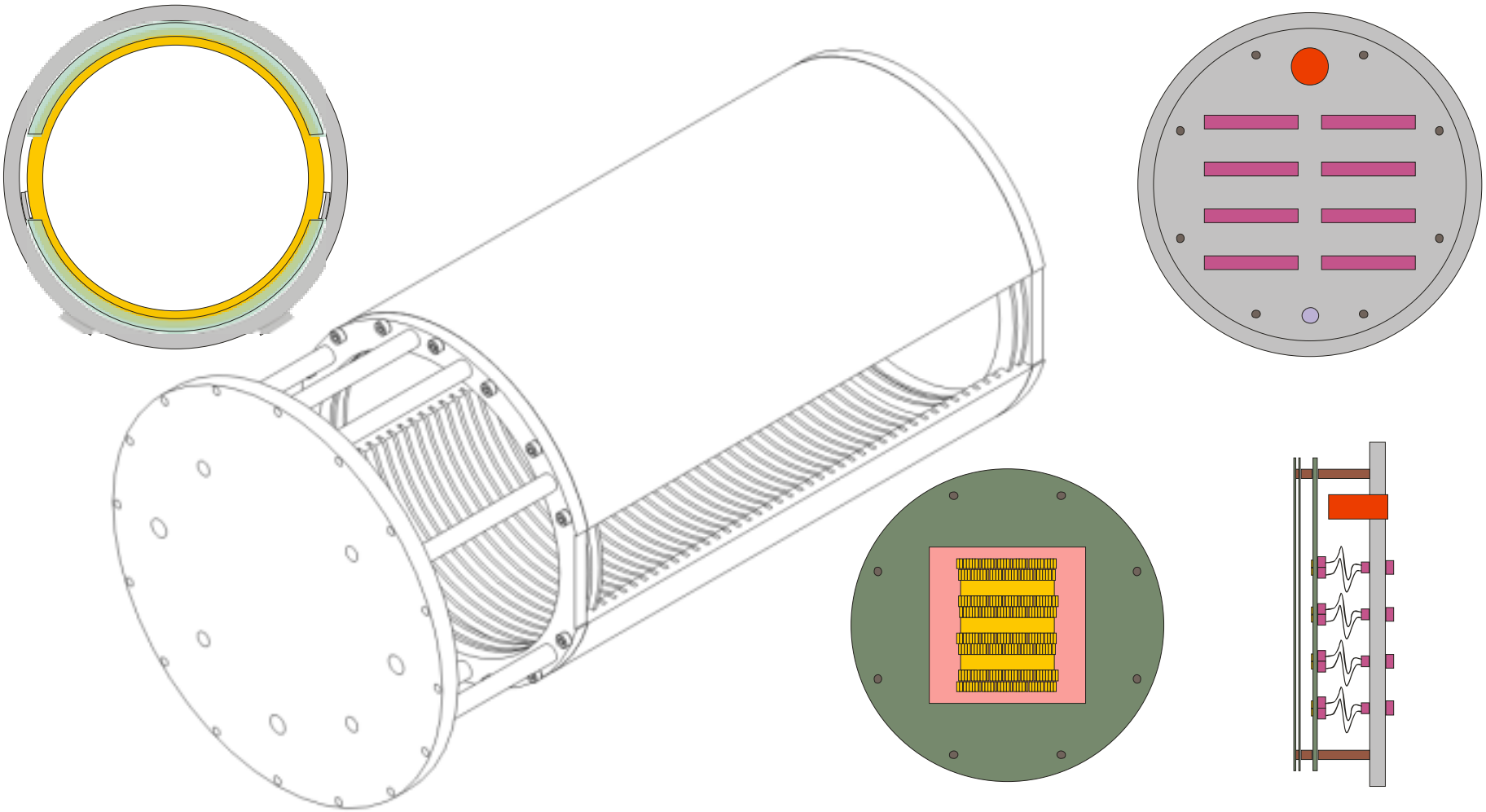
Construction of new TPC (TPC #2)

- Cylindrical: fits TRIUMF (1T) and DESY (5T) magnets
  - acrylic tubes, outer diameter 22.2 cm
  - Use STAR-TPC electronics (256 channels)



Construction of new TPC (TPC #2)

- 3D view of drift cage:



Summary

- Continuing to make progress on many fronts:
  - resistive sheets to disperse charge (induction signals)
  - cosmic tracking with direct charge signals
  - simulation package development
  - preparations for magnetic field tests
- Interested in test beam studies mid/late 2003:
  - test beam facilities?